Human–Wildlife Interactions 14(2):192–199, Fall 2020 • digitalcommons.usu.edu/hwi

Evaluating red wolf scat to deter coyote access to urban pastureland

Meghan M. Louis, Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University; and Environmental Medicine Consortium, North Carolina State University, Raleigh, NC 27607, USA

Samuel M. Tucker, Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University, Raleigh, NC 27607, USA

Michael K. Stoskopf, Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University; and Environmental Medicine Consortium, North Carolina State University, Raleigh, NC 27607, USA

Suzanne Kennedy-Stoskopf, Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University; and Environmental Medicine Consortium, North Carolina State University, Raleigh, NC 27607, USA *suzanne_stoskopf@ncsu.edu*

Abstract: Depredation of domestic livestock by wildlife is a leading source of human–wildlife conflict, often requiring intervention at the local level. Historically, these interventions have resulted in the use of lethal methods to remove the offending animal. In response to increased public opposition to lethal control methods, wildlife managers have sought to identify effective nonlethal biological options to mitigate wildlife depredations. In 2018, we tested the concept of a biological deterrent using red wolf (*Canis rufus*) scat that had historically been spread along fence lines to prevent depredation of lambs (*Ovis aries*) and kid goats (*Capra aegagrus hircus*) at the North Carolina State University College of Veterinary Medicine 32-ha Teaching Animal Unit (TAU), North Carolina, USA. To conduct the study, we deployed paired camera traps at 3 locations where we had previously observed coyotes (*C. latrans*) accessing the TAU. The study was conducted over a 94-day period alternating between no scat and freshly collected scat that was placed every 3 days from adult male red wolves. The study period overlapped lambing and kidding season. In addition to coyotes, the camera traps routinely detected red foxes (*Vulpes vulpes*) and raccoons (*Procyon lotor*). The red wolf scat we placed at the access point did not deter any of the mesocarnivores from entering the pasture.

Key words: camera trap, *Canis latrans*, *Canis rufus*, coyote, depredation, *Procyon lotor*, raccoon, red fox, red wolf, *Vulpes vulpes*

Depredation of domestic livestock by wildlife is a leading source of human–wildlife conflict, often requiring intervention at the local level (Sillero-Zubiri and Laurenson 2001). Livestock farms typically manage depredation through a combination of lethal and nonlethal approaches (Ferguson et al. 2017). Nonlethal controls that may have success include fencing, synchronized timing of births, shepherding, livestock guardian animals, and/or repellents that are visual, chemical, auditory, or olfactory (Ferguson et al. 2017). Lethal control is often deployed after nonlethal methods have proven ineffective or impractical (Knowlton et al. 1999). Lethal control can be controversial, and its long-term effectiveness can be equally difficult to quantify objectively (Treves et al. 2016).

The North Carolina State University (NC State) College of Veterinary Medicine (CVM), North Carolina, USA, maintains an on-campus working farm, the Teaching Animal Unit (TAU), to train veterinary students to manage and work safely around a variety of domestic livestock, including dairy and beef cattle (*Bos taurus*), goats (*Capra aegagrus hircus*), sheep (*Ovis aries*), and horses (*Equus caballus*). What was once a rural setting in the mid-twentieth century has changed to an urban landscape with major roads and highways surrounding the campus in the twenty-first century. Urban farming is on the rise (Butler 2012), and it is reasonable to assume that an associated increase in depredation by adaptive mesocarnivores like coyotes (*Canis latrans*) will follow.

Coyote populations began increasing around our study area in the 1990s, and the populations were well established by 2005 (North Carolina Resources Commission 2018). Observed depreda-

Figure 1. An endangered red wolf (*Canis rufus*; *photo courtesy of D. Margarucci*).

tion of lambs and kid goats in the TAU by coyotes began in 2008 (S. B. Ruth, TAU, personal communication). Installation of electrified woven wire netting for the sheep and goat pastures occurred. Improved fencing was insufficient to eliminate depredation, so a contracted wildlife management team trapped and dispatched the coyotes. Since the last coyote removal in 2011, there has been no depredation on livestock despite continued sightings of coyotes.

Five red wolf (*C. rufus*; Figure 1) adults arrived into a facility located within our study area in 2012. North Carolina has been at the center of the Red Wolf Recovery Plan that involves a captive breeding program and reintroduction efforts. The facility and wolves are part of the Red Wolf Species Survival Plan, which helps manage the species in captivity.

Students broadcast red wolf scat along the sheep and goat pens in an attempt to discourage coyotes. The idea is to create a biological fence, which refers to a natural boundary of scent marks that mimic territorial scent marks of neighboring wildlife (Ausband et al. 2013, Anhalt et al. 2014). The efficacy of this practice is not known. Urine and scat from various carnivore species have been used to evaluate the effects of scent marking on territoriality and behavior (Paquet 1991, Gese and Ruff 1997, Apfelbach et al. 2005). Biological fences have been studied intraspecifically with wolves and coyotes, but we are unaware if similar studies have been conducted to evaluate interspecific reactions between red wolves and coyotes.

Using camera traps, we documented frequency of access to the study area by coyotes, red foxes (*Vulpes vulpes*), and raccoons (*Procyon lotor*) during lambing and kidding season before and after the addition of red wolf scat. Farm managers were interested if red wolf scat would deter the mesocarnivores from using a pasture that serves as a corridor into the entire farm. We hypothesized that the introduction of red wolf scat along points of entry into the pasture would decrease coyote, red fox, and raccoon activity in the study area.

Study area

Our study was at NC State CVM, in Raleigh, North Carolina (Figure 2A). The CVM maintains the TAU, a 32-ha working farm adjacent to the CVM teaching buildings and veterinary hospital. Within the TAU, House Creek drains a 2-ha pond and provides a western boundary to a pasture used for beef and dairy cattle. House Creek continues through a culvert under a major 6-lane road, Wade Avenue, to drain into the Neuse River Basin. House Creek branches prior to the culvert to run parallel to Wade Avenue before dead-ending at a cloverleaf interchange (Figure 2B).

We chose a 2-ha area in the TAU to conduct our study. This area was chosen to triangulate movement patterns using creek beds as conduits of movement by coyotes, raccoons, and red foxes. Initial deployment of camera traps, based on topography and the presence of House Creek, identified 3 crossings regularly used by mesocarnivores. Specifically, we selected a natural sand and substrate bridge of House Creek (site 1), the culvert under Wade Avenue (site 2), and a natural branching point of House Creek (site 3).

Methods

We conducted the study from February to May 2018 (NCSU IACUC 18-029-O). We deployed Browning Strike Force HD Pro cameras (Browning, Morgan, Utah, USA) at each of the 3 crossing points using wooden stakes or creek-side trees. An additional camera of another model type supplemented the Browning Strike Force HD at each location: (1) Bushnell Trophy Cam HD Aggressor (Bushnell Outdoor Products, Overland Park, Kansas, USA) digital camera (n = 2); and (2) Reconyx Hyperfire HC 600 (Reconyx, Inc., Holmen, Wisconsin, USA)

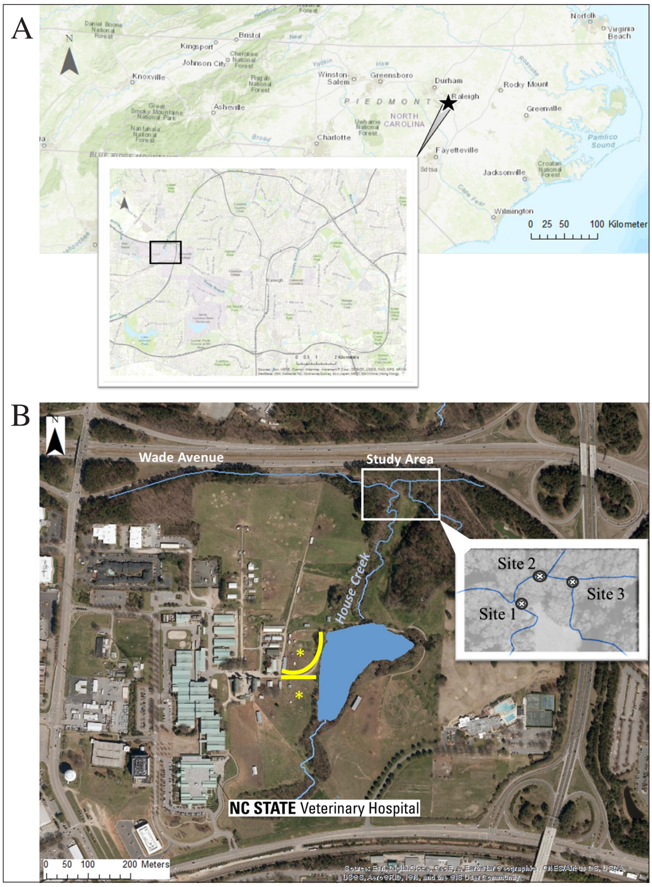


Figure 2. (A) Overview of the state of North Carolina, USA, with the city of Raleigh highlighted. The black rectangle highlights the region displayed in Figure 2B. (B) North Carolina State University College of Veterinary Medicine, Raleigh, North Carolina, USA. Solid yellow lines indicate the fence lines where veterinary students distributed red wolf (*Canis rufus*) scat. Yellow stars indicate pastures where lambs (*Ovis aries*) and kid goats (*Capra aegagrus hircus*) are kept (*courtesy World Imagery; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USD*).

digital camera (n = 1). The cameras were set at each location opposite each other to prevent missed captures using their optimal detection zones. The cameras we deployed were commercially available with similar specifications of fast trigger times (<0.6 seconds) and infrared flashes. Thus, we did not attempt to compare detection rates between camera brands.

We separated our study period into blocks of time (consecutive days) of either scat introduction or no scat introduction. No scat introduction served as our control period (C1) and was 28 days long (February 18 to March 18, 2018). The scat introduction period (S1) of 28 days was from March 21 until April 17, 2018. We waited 10 days and conducted a 14-day pattern of recording mesocarnivore movements again with no scat (C2; April 27 to May 10, 2018) and with scat (S2; May 15 to May 28, 2018). We physically checked cameras and downloaded the photos every 3 days during both the scat introduction and control time periods.

During the scat introduction (S1, S2), volumetric samples (each measuring 115 g) of fresh scat representing average sized scats were collected from the enclosures of 2 intact, adult male red wolves. We collected the scat immediately prior to placement at camera sites and placed them in 100% natural cotton cheesecloth (Regency Wraps, Dallas, Texas, USA) to allow for easy recovery and replacement and to be recognizable on camera. At each location, scat placement occurred in view of both cameras and repeated every 3 days, approximating the time interval used to broadcast scat along fence lines during lambing and kidding season. During this study, students continued to broadcast scat along fence lines. Red wolf fecal examinations are conducted quarterly and are negative for parasite ova that might contaminate the farm environment.

We chose the spring season for this study to encompass the lambing and kidding season, the breeding seasons for both the coyote (January to March) and raccoon (February to April), and the whelping season for the red fox (February to April; North Carolina Wildlife Resources Commission 2017, 2018). Because the TAU is a working farm, we chose to conduct the study over 1 season to minimize disruption to pasture rotation for cattle.

Data analysis

We separated a 24-hour day or trap night into 24 1-hour time blocks from 0000 to 2300 hours that began each hour. We set the independence interval at 60 minutes, which is the delay period between counted photos for a given species (Si et al. 2014). We defined detection as a photo cap-

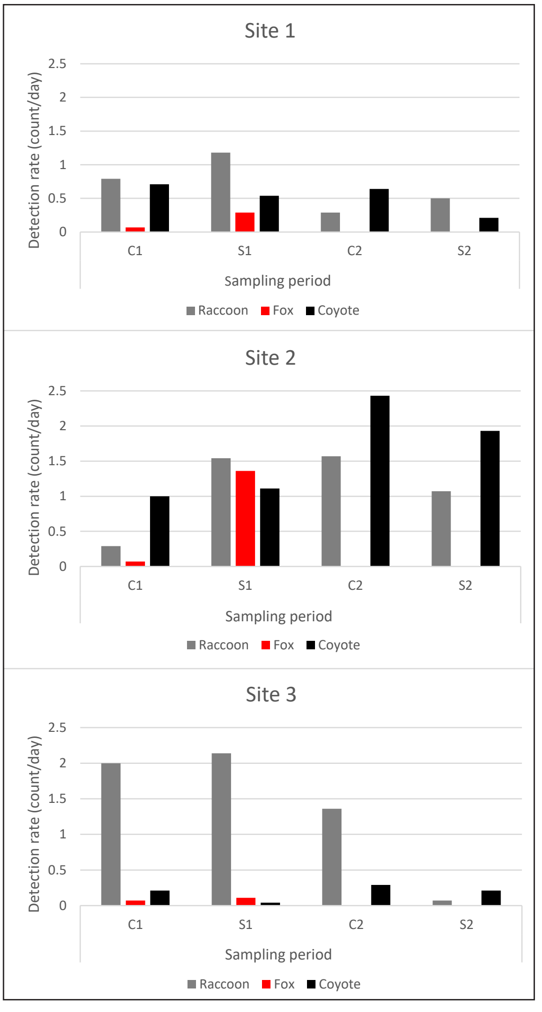


Figure 3. Spatial portioning of camera trap sites 1, 2, and 3 by raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), and coyotes (*Canis latrans*) during sampling periods C1 (control), S1 (scat treatment), C2 (control), and S2 (scat treatment). Data was collected from camera traps, February to May 2018, at North Carolina State University College of Veterinary Medicine Teaching Animal Unit in Raleigh, North Carolina, USA.

ture of a coyote, raccoon, or fox, within the hour time intervals at a trapping location regardless of the number of individuals or number of photos taken within that hour. The time intervals were reported as positive or negative for each mesocarnivore species at each site.

The number of positive hours were directly compared across each mesocarnivore species during both the scat introduction and control time periods to evaluate if the mesocarnivores changed their spatial and temporal patterns in response to the scat introduction. The number of positive hours for each species (coyote, raccoon, fox) divided by the total number of trap nights within each sampling period (C1, S1, C2, S2) for each site (1, 2, 3) equaled the detection rate.

We used chi-squared tests to compare total observed and expected positive trap nights for each species during the control and treatment time periods (Microsoft Office 365, Excel version 2004). Significance was set at $\alpha = 0.05$. Photo evidence of behavioral responses to the scat introduction was annotated along with any physical evidence of overmarking.

Results

There was no evidence of avoidance, with detection rates nearly identical during control (C1 + C2) and treatment periods (S1 + S2) for coyotes (28% of nights vs. 29%) and raccoons (30% vs. 30%) across all 3 sites. Red foxes appeared to be attracted to the scat, as they were only detected 3 times during control but were detected 38 times (30% of trap nights) during the 2 treatment periods. There was no evidence of association between detections with control and treatment for coyotes or raccoons (P = x and y, respectively); however, foxes did show evidence of association ($P < 0.01$). Detection rates are graphically presented by site, species, and time period (Figure 3).

The nocturnal nature of foxes and raccoons was demonstrated with consistent overlap of peak movement times (Figure 4). In contrast, coyote movement did not show any periodicity (Figure 4). No 2 species were detected at the same location at the exact same time. Raccoons were detected more often at site 3 in both the control and scat placement, whereas coyotes were more often detected at site 2 in both time periods. Foxes were equally dispersed during the control blocks but had a higher detection rate at site 2 during the scat placement (Figure 3).

Investigative behavior of sniffing and overmarking occurred in all 3 observed species with the introduction of red wolf scat. Sniffing was detected in 5/80 (6%) of positive hours for coyotes, 19/167 (11%) of positive hours for raccoons, and 2/49 (4%) of positive hours for foxes. Coyotes were the only species seen to overmark the red wolf scat with urine. There was 1 incident of fecal overmarking that was not detected on camera, but the physical appearance of the scat and abundant tracks were characteristic of a coyote.

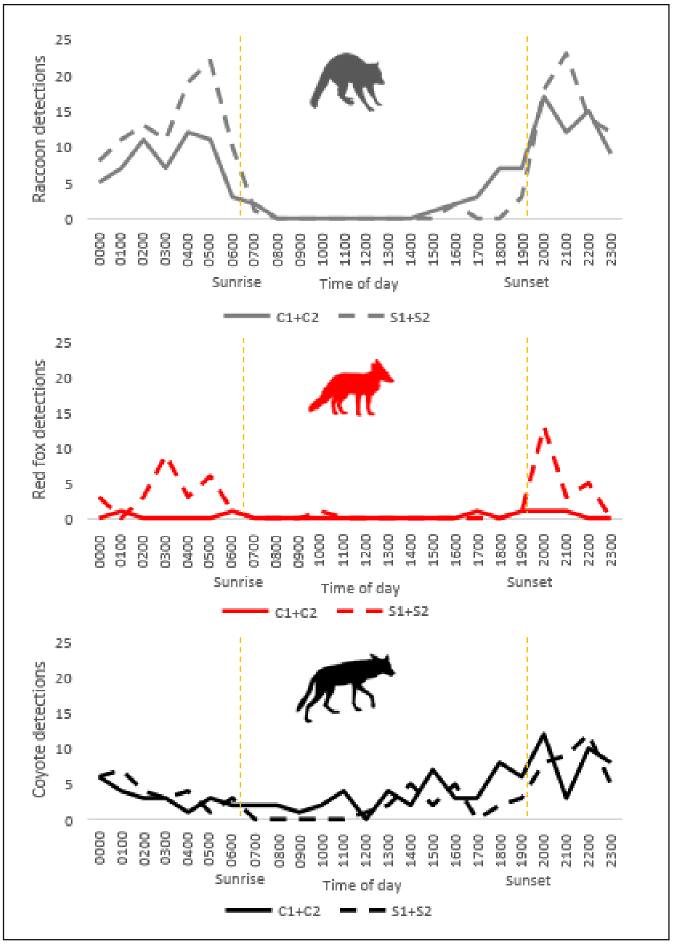


Figure 4. Temporal patterns of detections by raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), and coyotes (*Canis latrans*) during the control (C1 + C2) represented by the solid line, and red wolf (*C. rufus*) scat treatment (S1 + S2) represented by the dashed line, between February to May 2018, at North Carolina State University College of Veterinary Medicine Teaching Animal Unit in Raleigh, North Carolina, USA. Orange dashed lines indicate sunrise and sunset (*images from N. Sinegina and B. Comix, https://www.supercoloring.com/silhouettes/*).

Discussion

Red wolf scat as a biological deterrent to decrease depredation of lambs and kids by coyotes was thought to have been beneficial by TAU staff, even though cause and effect were never tested. The results of this study demonstrate that red wolf scat did not deter either coyotes or raccoons from accessing the pasturelands, and it might even attract foxes.

Interspecific interactions are complex, and cause and effect relationships are often difficult to establish. Regular movement of coyotes, raccoons, and foxes into the pasture suggest established temporal and spatial partitioning locally between the species. We noted behavioral differences between species in their responses to the introduction of red wolf scat. The behavioral overmarking of both urine and feces by coyotes indicates that olfactory messages were being broadcast. Male red wolf scat was chosen to avoid signals of estrus that could serve as an attractant since coyote and red wolf hybridization has been documented within the literature (Adams et al. 2003, Kays et al. 2010, Gese et al. 2015). Similar to the findings of Paquet (1991), coyotes did not avoid areas that we artificially marked with red wolf scat, nor did they minimize the evidence of their own activity. Daytime movement and lack of periodicity of coyote travel patterns within this study may be secondary to an active coyote den site found within the TAU in late May. We did not design the study to detect if the presence of scat had any broader scale impact on mesocarnivore travel patterns.

Fox photo captures increased during scat introduction blocks (S1 and S2) compared to control blocks (C1 and C2). A study assessing the visitation rate of red fox to lynx (*Lynx lynx*) scat found that red foxes visited scat-treated plots more frequently and longer than control plots (Wikenros et al. 2017). The variable detection rate for the red fox between S1 and S2 may be related to their whelping season in North Carolina (North Carolina Wildlife Resources Commission 2017). During S2, red foxes would most likely have had pups and be spending time closer to their burrows. It is also possible that foxes sought to avoid areas where coyotes were active (Voigt and Earle 1983). There was, however, an abundance of fox and coyote sightings in December and January during breeding season when placement of camera traps for the study was being evaluated.

Raccoons did not avoid red wolf scat or show outward signs of increased awareness, other than the 11% smelling that occurred with the introduced scat, which was more frequent than coyotes and foxes combined. Red wolf predation on raccoons has been minimally documented. Raccoon was identified in only 4/179 (2%) of red wolf scats analyzed for dietary composition in the Red Wolf Recovery Program area in eastern North Carolina (McVey et al. 2013). In a study similar to ours, Gehrt and Prange (2007) found that raccoons did not avoid specific sites that had been marked with coyote urine (Gehrt and Prange 2007). Historically, it was hypothesized that coyotes demonstrated a significant predation risk to raccoons. However, Gehrt and Clark (2003) summarized radio telemetry studies (Clark et al. 1989, Hasbrouck et al. 1992, Chamberlain et al. 1999, Gehrt and Fritzell 1999, Prange et al. 2003) and reported a <3% predation rate of coyotes toward raccoons. The lack of substantial detection rate change between control and red wolf scat treatment and concurrent presence of coyotes may reflect low concern by raccoons for predation by wild canids (Gehrt and Clark 2003).

Depredation control is multi-factorial. The CVM ensures that the fences are well maintained. The veterinary students continue to broadcast red wolf scat every 3 days during lambing and kidding season along these pastures. Whether the red wolf scat plays a role in reducing depredation remains uncertain, but the effort appears worthwhile to the students and farm management in limiting the potential for negative human–wildlife interactions.

Management implications

This was a time-limited study focused on a small focal area that is proxy to what a rancher or farm manager can do. There was no evidence that red wolf scat acted as a biological deterrent to mesocarnivore movement into a pasture that provides access to the entire farm. A camera trap study focused along the sheep and goat fence lines during lambing and kidding seasons would be useful to observe coyote reactions to red wolf scat. Interpreting the impact on depredation would be difficult to assess, as 2 guard dogs and new fencing have been added since this study was conducted. In addition, former coyote den sites have been disrupted and are no longer used. We believe that biological deterrents may play a role in discouraging coyote depredation when used in conjunction with other management strategies, but they require further study.

Acknowledgments

We thank the TAU staff at NC State CVM for their assistance and to R. Kays and J. Niemuth for their insights. The Environmental Medicine Consortium, North Carolina State University, provided the funding for this study. Comments provided by C. Lackey, HWI associate editor, and 2 anonymous reviewers greatly improved earlier versions of our paper.

Literature cited

Adams, J. R., B. T. Kelly, and L. P. Waits. 2003. Using faecal DNA sampling and GIS to monitor hybridization between red wolves (*Canis rufus*) and coyotes (*Canis latrans*). Molecular Ecology 12:2175–2186.

Anhalt, C. M., T. R. Van Deelen, R. N. Schultz, and A. P. Wydeven. 2014. Effectiveness of a simulated pack to manipulate wolf movements. Human–Wildlife Interactions 8:210–217.

Apfelbach, R., C. D. Blanchard, R. J. Blanchard, R. A. Hayes, and I. S. McGregor. 2005. The effects of predator odors in mammalian prey species: a review of field and laboratory studies. Neuroscience & Biobehavioral Reviews 29:1123–1144.

Ausband, D. E., M. S. Mitchell, S. B. Bassing, and C. White. 2013. No trespassing: using a biofence to manipulate wolf movements. Wildlife Research 40:207–216.

Butler, W. H. 2012. Welcoming animals back to the city: navigating the tensions of urban livestock through municipal ordinances. Journal of Agriculture, Food Systems, and Community Development 2:193–215.

Chamberlain, M. J., K. M. Hodges, B. D. Leopold, and T. S. Wilson. 1999. Survival and cause-specific mortality of adult raccoons in central Mississippi. Journal of Wildlife Management 63:880–888.

Clark, W. R., J. J. Hasbrouck, J. M. Kienzler, and T. F. Glueck. 1989. Vital statistics and harvest of an Iowa raccoon population. Journal of Wildlife Management 53:982–990.

Ferguson, D., C. Lee, and A. Fisher. 2017. Advances in sheep welfare. Woodhead Publishing, Sawston, Cambridge, United Kingdom.

Gehrt, S. D., and W. R. Clark. 2003. Raccoons, coyotes, and reflections on the mesopredator release hypothesis. Wildlife Society Bulletin 31:836–842.

Gehrt, S. D., and E. K. Fritzell. 1999. Survivorship of a nonharvested raccoon population in south Texas. Journal of Wildlife Management 63:889–894.

Gehrt, S. D., and S. Prange. 2007. Interference competition between coyotes and raccoons: a test of the mesopredator release hypothesis. Behavioral Ecology 18:204–214.

Gese, E. M., F. F. Knowlton, J. R. Adams, K. Beck, T. K. Fuller, D. L. Murray, T. D. Steury, M. K. Stoskopf, W. T. Waddell, and L. P. Waits. 2015. Managing hybridization of a recovering endangered species: the red wolf *Canis rufus* as a case study. Current Zoology 61:191–205.

Gese, E. M., and R. L. Ruff. 1997. Scent-marking by coyotes, *Canis latrans*: the influence of social and ecological factors. Animal Behaviour 54:1155–1166.

Hasbrouck, J. J., W. R. Clark, and R. D. Andrews. 1992. Factors associated with raccoon mortality in Iowa. Journal of Wildlife Management 56:693–699.

Kays, R., A. Curtis, and J. J. Kirchman. 2010. Rapid adaptive evolution of northeastern coyotes via hybridization with wolves. Biology Letters 6:89–93.

Knowlton, F. F., E. M. Gese, and M. M. Jaeger. 1999. Coyote depredation control: an interface between biology and management. Journal of Range Management 52:398–412.

McVey, J. M., D. T. Cobb, R. A. Powell, M. K. Stoskopf, J. H. Bohling, L. P. Waits, and C. E. Moorman. 2013. Diets of sympatric red wolves and coyotes in northeastern North Carolina. Journal of Mammalogy 94:1141–1148.

North Carolina Wildlife Resources Commission. 2017. North Carolina wildlife profiles. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA, <https://www.ncwildlife.org/Portals/0/Learning/documents/Profiles/RedFox_1.pdf>. Accessed October 4, 2019.

North Carolina Wildlife Resources Commission. 2018. Coyote management plan. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA, <https://www.ncwildlife.org/Portals/0/Learning/documents/Species/Coyote%20Management%20Plan_FINAL_030118.pdf>. Accessed October 4, 2019.

Paquet, P. C. 1991. Scent-marking behavior of sympatric wolves (*Canis lupus*) and coyotes (*C. latrans*) in Riding Mountain National Park. Canadian Journal of Zoology 69:1721–1727.

Prange, S., S. D. Gehrt, and E. P. Wiggers. 2003. Demographic factors contributing to high raccoon densities in urban landscapes. Journal of Wildlife Management 67:324–333.

Si, X., R. Kays, and P. Ding. 2014. How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. PeerJ 2:e374.

Sillero-Zubiri, C., and M. K. Laurenson. 2001. Interactions between carnivores and local communities: conflict or co-existence? Pages 282–312 *in* J. L. Gittleman, S. M. Funk, D. W. Macdonald, and R. K. Wayne, editors. Carnivore conservation: conservation biology. Volume 5. Cambridge University Press, Cambridge, United Kingdom.

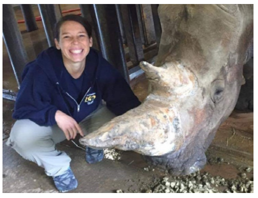
Treves, A., M. Krofel, and J. McManus. 2016. Predator control should not be a shot in the dark. Frontiers in Ecology and the Environment 14:380–388.

Voigt, D. R., and B. D. Earle. 1983. Avoidance of coyotes by red fox families. Journal of Wildlife Management 47:852–857.

Wikenros, C., M. Aronsson, O. Liberg, A. Jarnemo, J. Hansson, M. Wallgren, H. Sand, and R. Bergström. 2017. Fear or food–abundance of red fox in relation to occurrence of lynx and wolf. Scientific Reports 7:9059.

Associate Editor: Carl W. Lackey

Meghan M. Louis is a veterinarian specialized in wildlife medicine and an active duty Major in the U.S. Army Veterinary Corps. She has her B.S. degree in biology, M.S. degree in fisheries, wildlife, and conservation biology, and graduate certificate in military land sustainability. She completed a zoological medicine residency at North Carolina State University College of Veterinary Medicine and is a diplomat of the American College of Veterinary Preventive Medicine. She will be joining the 98th Civil Affairs Battalion (Airborne) and has particular interest in zoonotic disease and the human–wildlife interface.



Samuel M. Tucker will be graduating with his DVM from North Carolina State University College of Veterinary Medicine in 2021. He graduated from the University of Alabama with a B.S. degree in biology and a B.A. degree in English. He is currently a Second Lieutenant in the U.S. Army Veterinary Corps and will be promoted to a Captain upon graduation. He is interested in anesthesiology and anatomic pathology.

Michael K. Stoskopf is a professor in the Department of Clinical Sciences and director of the Environmental Medicine Consortium at North Carolina State University. He teaches health management of wildlife. He served as the chairperson for the Red Wolf Recovery Implementation Team for the U.S. Fish and Wildlife Service and serves on the Red Wolf Recovery Team.

Suzanne Kennedy-Stoskopf is professor emerita in the Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University. She taught wildlife diseases and was instrumental in creating links between Duke University and University of North Carolina-Chapel Hill to teach One Health principles across multiple disciplines.