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From the Field

Evaluating a Strategy to Deliver Vaccine to White-tailed Deer at a Landscape Level

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ABSTRACT Effective delivery of vaccines and other pharmaceuticals to wildlife populations is needed when zoonotic diseases pose a risk to public health and natural resources or have considerable economic consequences. The objective of our study was to develop a bait-distribution strategy for potential delivery of oral bovine tuberculosis (bTB) vaccine to white-tailed deer (*Odocoileus virginianus*) where deer are reservoirs for the disease. During 17 February and 2 March 2011, we created a grid of experimental bait stations ($n = 64$) on Sandhill Wildlife Management Area, Wisconsin, USA, to assess station densities needed to attract and deliver placebo baits to free-ranging white-tailed deer and look for associations among deer density, number of bait stations per deer, and bait consumption. We placed 1 L of commercially available alfalfa cubes at bait stations 652 m apart, and monitored stations with motion-activated cameras for 5 days to document visitation and consumption by deer and nontarget species. Deer discovered 38% of all bait stations within 37 hr, on average (SE = 3.91 hr), and consumed variable amounts of bait at each station. Deer were documented in 94% of all photographs of wildlife at bait stations. We found no correlation between bait consumption and deer density or the number of bait stations per deer. We provide the first information on use of baits by free-ranging deer and nontarget wildlife to eventually vaccinate deer against bTB at a landscape level. The results of this study can further the development of strategies in delivery of pharmaceuticals to free-ranging white-tailed deer. Published 2016. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS bait, bovine tuberculosis, bTB, disease transmission, motion-activated cameras, nontarget species, *Odocoileus virginianus*, vaccine delivery, white-tailed deer.

Successful oral vaccination campaigns have been achieved for several diseases, most notably rabies in North America and Europe (Slate et al. 2009); however, numerous complexities exist when wildlife are the disease reservoir (Cross et al. 2007). Overconsumption of baits by individuals and nontarget bait consumption and vaccine safety are all challenges that need to be addressed. The proportion of baits consumed by nontarget species (Campbell et al. 2006, Campbell and Long 2007, Bowman et al. 2015) should be quantified to determine economic feasibility and develop strategies to optimize species-specific delivery. Also, bait dispersal techniques (e.g., hand vs. aerial delivery) requires evaluation to determine which strategy is more technically and operationally feasible.

In northern Michigan, USA, white-tailed deer (*Odocoileus virginianus*) are the primary reservoir and maintenance host of bovine tuberculosis (bTB) and provide a source for infection to livestock. Traditional bTB-management strategies, such as reducing deer densities through hunter harvest, implementing bans on baiting, and improving cattle-producer biosecurity protocols have reduced apparent prevalence of bTB in deer, but public support for such measures are waning (O'Brien et al. 2006). The only

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commercially available vaccine (bacilli Calmette–Guerin or BCG) has proven effective, via oral delivery, in providing protection to captive white-tailed deer against bTB infection, but practical administration of BCG to free-ranging wildlife has not been assessed (Nol et al. 2008, Palmer et al. 2008, Ballesteros et al. 2009). Palmer et al. (2014) evaluated the palatability of molasses-based baits inoculated with BCG for oral delivery to captive white-tailed deer and observed repeated consumption and overconsumption.

An efficient and successful vaccination campaign for free-ranging white-tailed deer has not previously been evaluated or explored. For example, requirements such as the amount of bait needed, proper bait placement, and duration of prebaiting necessary to attract deer prior to delivering vaccine-laden baits are unknown. More importantly, even a minor vaccination campaign will likely only have a rudimentary habitat assessment via Geographic Information System layers available. Further, most vaccination campaigns likely do not have access to GPS-collared deer to assess local movements, resource use, deer densities by vegetation or landscape types or within the total area to be vaccinated, and bait density estimates needed to deliver vaccines to deer.

Monitoring bait sites with motion-activated cameras is an efficient and minimally invasive technique (Wolf et al. 2003, Campbell and Long, 2007, Smyser et al. 2015) to document bait availability and consumption by deer and nontarget species (Bowman et al. 2015). The white-tailed deer is a forest-dependent species; therefore, we focused our efforts, as most vaccination programs will for this species, on the forested landscape within the study area. In working toward an eventual program to vaccinate deer against bTB, our objective was to determine bait-site density needed without any *a priori* knowledge of deer movement, resource selection, or density in the study area. Our secondary objective was to determine bait-site visitation and feeding intensity by deer and nontarget species given a grid of experimental bait stations. We hypothesized that deer would find and consume our bait and the amount of bait provided would supply enough for a single family group.

STUDY AREA

We conducted our study on the Sandhill Wildlife Management Area (SWMA; 44°19′54″N, 90°9′53″W) located in central Wisconsin, USA (Fig. 1). Sandhill Wildlife Management Area was a 36.84-km^2 research facility surrounded by a 2.7-m-high woven-wire fence with controlled public access. The dominant upland vegetation or landscape types were aspen (*Populus* spp.) and oak (*Quercus* spp.) forest and scrub oak savanna, whereas marsh, lowland brush, open water, and numerous flowages occupied lowland sites. Sandhill Wildlife Management Area maintained an enclosed free-ranging deer population for research purposes and an aerial census conducted in January 2011 estimated 173 deer on the property (W. Hall, Wisconsin Department of Natural Resources, unpublished data).

METHODS

Bait Station Placement

Our goal was to systematically distribute feeding sites (hereafter referred to as bait stations) across SWMA such that deer would encounter them during normal foraging activities. We assumed that a deer home range at SWMA during the winter season was approximately 1.7 km^2, which is larger than reported home-range sizes for deer in southern Wisconsin's agriculture zone but smaller than home-range sizes for deer in more northern forested landscapes (Larson et al. 1978, Van Deelen et al. 1998, Magle et al. 2015). We chose to provide 4 temporary bait stations within each deer home range to maximize encounter rates. Therefore, we created a grid of 64 evenly spaced bait stations at 652 m between stations (or a quarter distance of 1.7 km^2 home range) within the SWMA boundary (Fig. 1). When we deemed proposed bait stations to be in areas of unsuitable winter deer habitat (i.e., open water, marsh, or bog), we shifted them to the nearest available suitable area (i.e., forest edge). We conducted this study during late winter when deer were most nutritionally stressed and in search of available forage, and when many nontarget species are minimally active (e.g., mesocarnivores and rodents in hibernation or torpor).

Bait Amounts and Monitoring

VerCauteren et al. (2003) found that deer in southwestern Wisconsin consumed a mean weight of dry matter from stored feed sites of 0.143 kg; thus, we assumed similar consumption rates at SWMA. We also assumed the average family group of deer included 4 individuals (Hawkins and Klimstra 1970). We placed 1 L (vol) of alfalfa cubes (Premium Alfalfa Cubes, Standlee Hay Company, Inc., Eden, ID, USA), or approximately 0.572 kg (0.143 kg $\times$ 4 deer), at each bait station (0.2–0.3-m^2 feeding area). Alfalfa cubes are readily consumed by deer and this quantity of bait was intended to be consumed by one family group and leave no residual, thus minimizing potential for nontarget consumption or congregation of multiple family groups of deer. The use of only 4 supplemental feeding sites at SWMA in a previous study, which were replenished with shelled corn for 12 days (Thompson et al. 2008), likely concentrated deer to these sites. We selected feeding in piles, which resulted in the highest feeding intensity when compared with raised feeding troughs (0.85 m high) and spread feed (2–3-m^2 feeding area; Thompson et al. 2008).

We divided the study into 2 different sampling periods (5-day intervals) because we did not have enough cameras to cover the entire study area in a single period. We also divided the study area into 4 quadrants (or 16 bait stations/quadrant) to address the potential for differing deer densities across the study area as well as differences in habitat configuration. We initiated sampling in the southwest and northeast quadrants on 17 February 2011 and initiated sampling in the northwest and southeast quadrants on 2 March 2011. The number of deer per quadrant (plus deer densities) was 36 (northeast; 4.31 deer/

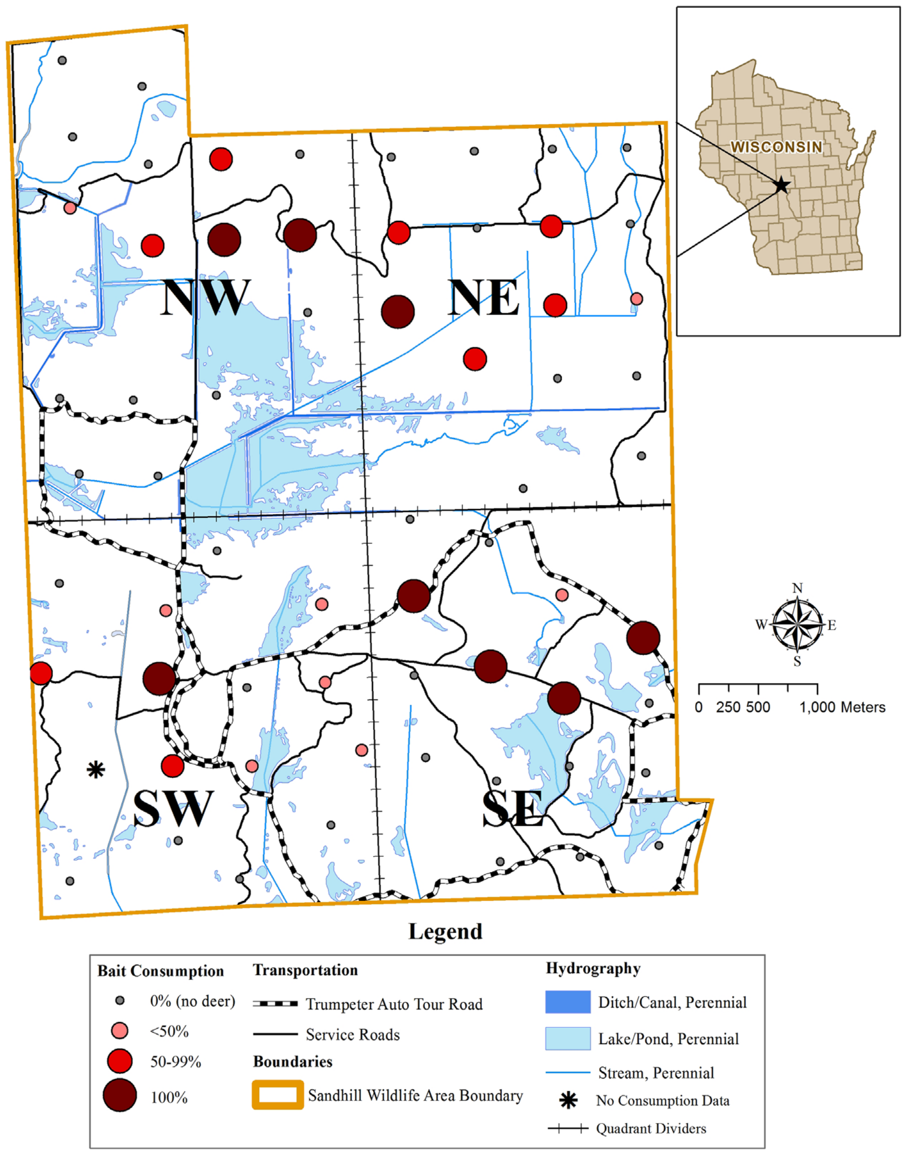

Figure 1. Location of 64 bait stations with percent bait consumed by white-tailed deer (*Odocoileus virginianus*) during an experimental bait-delivery evaluation (17 Feb and 2 Mar 2011) on Sandhill Wildlife Management Area, Wisconsin, USA.

km^2), 55 (northwest; 5.29 deer/km^2), 48 (southwest; 5.06 deer/km^2), and 34 (southeast; 3.96 deer/km^2; Fig. 1).

We used Silent Image® (Reconyx, LLP, LaCrosse, WI, USA) motion-activated digital cameras to monitor bait stations. We standardized bait-station configuration to ensure consistent field of view from the cameras. We installed cameras 1.8 m high and at a 20° angle focused downward on the bait station 5 m away. We programed cameras to capture images every 15 s for 15 min when wildlife activated cameras. Cameras only recorded activity within our trial area from which we determined average deer group-size, estimated bait consumption, and identified nontargets.

Data Coding and Analysis

We calculated visitation rates by wildlife entering the camera trial area (area ~2-m radius from bait station). Animals visiting bait stations were not individually identifiable; therefore, we summarized each wildlife photo as a unique event. We measured bait consumption at each bait station for 5 days on a 3-point Likert-based scale of 1, 2, 3 equal to <50%, 50–99%, and 100% bait consumed, respectively ("consumption rank"). If no deer visited a bait station, we assigned a consumption ranking of zero. For each quadrant, we also calculated the average consumption rank, number of bait stations per deer, and number of deer per forested square kilometer. To determine whether consumption was related to deer density, number of bait stations per deer, or number of deer per forested kilometer, we used a Spearman rank correlation analysis in the statistical program R (R Core Team, Vienna, Austria). We calculated average consumption rank by using only the consumption ranks of bait stations that were visited by deer in each quadrant. We omitted bait stations that were not visited by deer because we were only interested in the amount of bait consumption where consumption occurred. Incorporating bait stations where deer were not present would artificially depress average consumption amounts. We calculated the number of bait stations per deer by dividing the total number of bait stations by the number of deer in each quadrant. We combined deciduous and coniferous forest into one forest class to calculate the number of deer per forested areas in each quadrant. We used counts of visiting deer to calculate average deer group-size and deer-use minutes (DUM = [(no. of deer in image × 0.25 min)/camera-day]) to compare feeding intensity at each bait station (Beringer et al. 2003, Thompson et al. 2008). We did not model habitat variables with DUM or consumption rates because of the lack of variability across quadrants in habitat complexity and configuration. Furthermore, we wanted to limit our *a priori* study design to what would likely be available to researchers if a disease outbreak were to occur and a vaccination program was needed immediately.

RESULTS

We recorded 5,562 digital images of wildlife during both sampling periods, with the vast majority consisting of deer (94%). Average deer group-size at bait stations was 1.17 deer (range = 1–4). Other species visiting bait stations included grey squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), otter (*Lontra canadensis*), ruffed grouse (*Bonasa umbellus*), coyote (*Canis latrans*), and bobcat (*Lynx rufus*). The majority of bait stations had no visitation by deer (62%; $n = 39$). At bait stations visited by deer, consumption rates were equal between Likert categories (i.e., <50%, $n = 8$; 50–99%, $n = 8$; 100% $n = 8$; Fig. 1). One bait station was removed from analysis because the camera shifted and was not focused on the bait. Average (±SE) time to deer encountering bait stations was 37 hr (±3.91 hr). Average (±SE) time to consumption of 50% and 100% of the bait was 53 hr (±8.33 hr) and 70 hr (±9.13 hr), respectively.

We found that the southwest quadrant had the greatest number of bait stations visited by deer ($n = 8$); however, those visitations yielded the lowest average consumption ($\bar{x} = 1.50$, SE ± 0.27) and deer group-size ($\bar{x} = 1.08$, SE ± 0.01; Table 1). This quadrant also had the lowest average DUM ($\bar{x} = 5.29$, SE ± 3.02; Table 1) at bait stations. The northeast quadrant had the second highest number of bait stations visited by deer ($n = 6$) and, similar to the southwest quadrant, yielded the second lowest average consumption ($\bar{x} = 2.00$, SE ± 0.26; Table 1). We found the average deer group-size for the northeast quadrant was second highest amongst all quadrants ($\bar{x} = 1.20$, SE ± 0.01), resulting in the highest average DUM ($\bar{x} = 20.89$, SE ± 5.52; Table 1). The southeast and northwest quadrants had the lowest number of bait stations visited by deer ($n = 5$) and yielded the 2 highest average consumption ranks ($\bar{x} = 2.60$, SE ± 0.40 and $\bar{x} = 2.20$, SE ± 0.37, respectively; Table 1). The southeast and northwest quadrants also had similar DUM scores ($\bar{x} = 10.61$, SE ± 2.78 and $\bar{x} = 10.62$, SE ± 3.43), with average deer group-sizes of 1.25 (SE = 0.02) and 1.12 (SE = 0.01), respectively (Table 1). We found no correlation between consumption and the number of bait stations per deer ($r^2 = 0.24$, $P = 0.27$), deer density ($r^2 = -0.24$, $P = 0.27$), or deer per forested square kilometer ($r^2 = -0.24$, $P = 0.27$).

DISCUSSION

We found bait-station discovery and consumption by deer on SWMA to be variable. Even after deer found our bait stations, consumption of all bait occurred only 33% of the time. Our results also suggest that the baiting quantity and density prevented multiple family groups from congregating at sites and sharing of bait. This might have been due to us providing enough bait for a family group-size of 4, when the mean deer group-size was actually 1.17 or approximately 70% less than what we had expected. Additionally, deer at SWMA had no prior knowledge of alfalfa or alfalfa cubes. This could have affected bait discovery and consumption and suggests that more prebaiting could occur to "train" deer if *a priori* study design permitted. Another factor affecting bait consumption may have been difficulty of deer finding bait stations. We had approximately 1 bait station/0.36 deer (or 2.7 deer/bait station), which equated to 1.7 bait stations/km^2 and may not have been enough for deer in the area to encounter during daily activities. Additionally, our bait stations were only accessible to deer for 5 days to minimally affect movements of deer because others have found that daily placement of bait concentrated deer activity at bait sites (Thompson et al. 2008) and deer shifted core areas or established new ones closer to bait sites in response to baiting (Kilpatrick and Stober 2002). Though our initial baiting grid was modified by moving bait stations originally located in

Table 1. Parameters used to explain white-tailed deer (*Odocoileus virginianus*) activity at experimental bait stations during 17 February and 2 March 2011 on Sandhill Wildlife Management Area, Wisconsin, USA.

	Northeast		Southwest		Northwest		Southeast	
Variable	$\bar{x}$	**SE**	$\bar{x}$	**SE**	$\bar{x}$	**SE**	$\bar{x}$	**SE**
Period	Feb (snow)		Feb (snow)		Mar (no snow)		Mar (no snow)	
Quadrant area (km^2)	8.36		9.49		10.41		8.59	
No. of stations	16		15		16		16	
With deer visitation	6		8		5		5	
Deer density (deer/km^2)	4.31		5.06		5.29		3.96	
Forested areas (deer/km^2)	9.40		11.54		13.92		7.08	
Bait station density (stations/deer)	0.44		0.31		0.29		0.47	
Consumption (Likert-based)	2.00	0.26	1.50	0.27	2.20	0.37	2.60	0.40
Deer-use minutes (DUM)	20.89	5.52	5.29	3.02	10.62	3.43	10.61	2.78
Mean deer group size	1.20	0.01	1.08	0.01	1.12	0.01	1.25	0.02

marginal habitats (i.e., open water, marsh, or bog) to forested upland areas, deer still found and consumed bait at just 38% of the stations. However, we found consumption at the quadrant level appeared to be relatively consistent despite high variability among bait site use within a quadrant.

The amount of time (DUM) deer spent at bait stations also varied considerably. Deer spent almost 4 times longer at bait stations in the northeast quadrant compared with the southwest quadrant. Although we documented similar DUM values for the northwest and southeast quadrants, Thompson et al. (2008) observed DUM values (feeding in pile method) in the southeast quadrant of SWMA that were 13 times higher. Greater deer densities during previous research ($n = 13$ deer/km^2 [2003–2004] and $n = 7$ deer/km^2 [2004–2005]) on SWMA and bait that was replenished daily may explain such high DUM values (Thompson et al. 2008).

Although we did not find any relationships with consumption, this was likely a result of our small sample size ($n = 4$ quadrants) and lack of variability in deer density across our study area, which limits broad inference to similar bait-distribution strategies across similar habitats. Intuitively, as more deer occupy an area then more deer are capable of encountering and consuming food resources. Average group size was relatively equal across all quadrants and the quadrants with the highest consumption rank (NW and SE) also had the lowest number of bait stations visited by deer. Therefore, deer may have been concentrated in certain areas within the northwest and southeast quadrants before study initiation, demonstrating that bait station placement in high-use areas may be more important than the number of bait stations placed on the landscape, especially during times when deer foraging and movement may be limited (i.e., winter and deep snow). Compressed winter home ranges may also explain the low visitation rates we observed for deer to bait stations during our study (Tierson et al. 1985, Sitar 1996).

Diverse challenges exist that may prevent the success of many wildlife vaccination programs, including wildlife population dynamics, nontargets, disease transmission rates, and cost-effectiveness of vaccination programs. One advantage of our bait matrix was that the vast majority of wildlife visiting bait stations and consuming bait was deer. As such, we speculate that when using bait formulations that primarily appeal to deer, this bait delivery system is a viable option to vaccinate deer from disease (although see Palmer et al. 2014). However, placement of bait stations at equal intervals may need to be adapted. Deer exhibit greater use along habitat edges (Williamson and Hirth 1985, Alverson et al. 1988), so placement of bait stations in these areas may increase the chance of bait being encountered and consumed. Furthermore, if data exist and time permits, spatially explicit and individual-based modeling of deer movements may provide further insight into the most efficient density and placement of bait stations to ensure high vaccination rates (Eisinger and Thulke 2008, Lange et al. 2012).

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LITERATURE CITED

Alverson, W. S., D. M. Waller, and S. L. Solheim. 1988. Forests too deer: edge effects in northern Wisconsin. Conservation Biology 2:348–358.

Ballesteros, C., J. M. Garrido, J. Vicente, B. Romero, R. C. Galindo, E. Minguijón, M. Villar, M. P. Martín-Hernando, I. Sevilla, R. Juste, A. Aranaz, J. de la Fuente, and C. Gortázar. 2009. First data on Eurasian wild boar response to oral immunization with BCG and challenge with a *Mycobacterium bovis* field strain. Vaccine 27:6662–6668.

Beringer, J., K. C. VerCauteren, and J. J. Millspaugh. 2003. Evaluation of an animal activated scarecrow and a monofilament fence for reducing deer use of soybean fields. Wildlife Society Bulletin 31:492–498.

Bowman, B., J. L. Belant, D. E. Byer, and D. Martel. 2015. Characterizing nontarget species use at bait sites for white-tailed deer. Human-Wildlife Interactions 9:110–118.

Campbell, T. A., S. J. Lapidge, and D. B. Long. 2006. Using baits to deliver pharmaceuticals to feral swine in southern Texas. Wildlife Society Bulletin 34:1184–1189.

Campbell, T. A., and D. B. Long. 2007. Species-specific visitation and removal of baits for delivery of pharmaceuticals to feral swine. Journal of Wildlife Diseases 43:485–491.

Cross, M. L., B. M. Buddle, and F. E. Aldwell. 2007. The potential of oral vaccines for disease control in wildlife species. The Veterinary Journal 174:472–480.

Eisinger, D., and H.-H. Thulke. 2008. Spatial pattern formation facilitates eradication of infectious diseases. Journal of Applied Ecology 45:415–423.

Hawkins, R. E., and W. D. Klimstra. 1970. A preliminary study of the social organization of white-tailed deer. Journal of Wildlife Management 34:407–419.

Kilpatrick, H. J., and W. A. Stober. 2002. Effects of temporary bait sites on movements of suburban white-tailed deer. Wildlife Society Bulletin 30:760–766.

Lange, M., S. Kramer-Schadt, and H.-H. Thulke. 2012. Efficiency of spatio-temporal vaccination regimes in wildlife populations under different viral constraints. Veterinary Research 43:37.

Larson, T. J., O. J. Rongstad, and F. W. Terbilcox. 1978. Movement and habitat use of white-tailed deer in southcentral Wisconsin. Journal of Wildlife Management 42:113–117.

Magle, S. B., L. H. Kardash, and A. O. Rothrock. 2015. Movements and habitat interactions of white-tailed deer: implications for chronic wasting disease management. American Midland Naturalist 173:267–282.

Nol, P., M. V. Palmer, W. R. Waters, F. E. Aldwell, B. M. Buddle, J. M. Triantis, L. M. Linke, G. E. Phillips, T. C. Thacker, J. C. Rhyan, M. R. Dunbar, and M. D. Salman. 2008. Efficacy of oral and parenteral routes of *Mycobacterium bovis* bacille Calmette-Guerin vaccination against experimental bovine tuberculosis in white-tailed deer (*Odocoileus virginianus*): a feasibility study. Journal of Wildlife Diseases 44:247–259.

O'Brien, D. J., S. M. Schmitt, S. D. Fitzgerald, D. E. Berry, and G. J. Hickling. 2006. Managing the wildlife reservoir of *Mycobacterium bovis:* the Michigan, USA, experience. Veterinary Microbiology 112:313–323.

Palmer, M. V., M. R. Stafne, W. R. Waters, T. C. Thacker, and G. E. Phillips. 2014. Testing a molasses-based bait for oral vaccination of white-tailed deer (*Odocoileus virginianus*) against *Mycobacterium bovis*. European Journal of Wildlife Research 60:265–270.

Palmer, M. V., T. C. Thacker, and W. R. Waters. 2008. Vaccination with *Mycobacterium bovis* BCG strains Danish and Pasteur in white-tailed deer (*Odocoileus virginianus*) experimentally challenged with *Mycobacterium bovis*. Zoonoses and Public Health 56:243–251.

Sitar, K. L. 1996. Seasonal movements, habitat use patterns, and population dynamics of white-tailed deer (*Odocoileus virginianus*) in an agricultural region of northern Lower Michigan. Dissertation, Michigan State University, Ann Arbor, USA.

Slate, D., T. P. Algeo, K. M. Nelson, R. B. Chipman, D. Donovan, J. D. Blanton, M. Niezgoda, and C. E. Rupprecht. 2009. Oral rabies vaccination in North America: opportunities, complexities, and challenges. PLoS Neglected Tropical Diseases 3:e549.

Smyser, T. J., J. V. Redding Jr., C. M. Bevis, L. K. Page, and R. K. Swihart. 2015. Development of an automated dispenser for delivery of medicinal or vaccine-laden baits to raccoons (*Procyon loter*). Journal of Wildlife Diseases 51:513–518.

Thompson, A. K., M. D. Samuel, and T. R. van Deelen. 2008. Alternative feeding strategies and potential disease transmission in Wisconsin white-tailed deer. Journal of Wildlife Management 72:416–421.

Tierson, W. C., G. F. Mattfeld, R. W. Sage, and D. F. Behrend. 1985. Season movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49:760–769.

Van Deelen, T. R., H. Campa III, M. Hamady, and J. B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. Journal of Wildlife Management 62:205–213.

VerCauteren, K. C., M. Pipas, P. Peterson, and S. Beckerman. 2003. Stored-crop loss due to deer consumption. Wildlife Society Bulletin 31:578–582.

Williamson, S. J., and D. H. Hirth. 1985. An evaluation of edge use by white-tailed deer. Wildlife Society Bulletin 13:252–257.

Wolf, K. N., F. Elvigner, and J. L. Pilcicki. 2003. Infrared-triggered photography and tracking plates to monitor oral rabies vaccine bait contact by raccoons in culverts. Wildlife Society Bulletin 31:387–391.

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