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Deer guards and bump gates for excluding white-tailed deer from fenced resources

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Abstract: White-tailed deer (*Odocoileus virginianus*) causing damage is a reoccurring theme in the realm of wildlife damage management, especially regarding human safety, disease transmission, and agricultural losses. Fences often are the only reliable long-term nonlethal means of controlling deer damage. The efficacy of fences, however, relies on their weakest link: human-operated gates. Although not overly time-consuming, the act of closing a gate appears to be a burden to individuals, resulting in open-access to an otherwise protected resource. We examined the efficacy of 2 alternatives to traditional gates to evaluate their potential to be used for excluding or containing deer. We evaluated a commercially available kit for mechanically opening and closing gates and a modified deer guard that resembles a common cattle guard but incorporates bearing-mounted rollers as cross members. The gate kit proved effective in restricting deer access to bait throughout the study, but, in supplemental evaluations, we observed excessive rates of functional failure. Deer guards reduced deer entry into exclosures, but efficacy declined with time as deer walked and jumped across guards. With some refining, both guards and gates have potential to be useful components of an integrated biosecurity strategy.

Key words: bovine tuberculosis, Bump Gate©, cattle, deer guard, disease transmission, gate, human–wildlife conflicts, *Odocoileus virginianus*

White-tailed deer (*Odocoileus virginianus*) populations have greatly increased across the United States in the last 25 years, creating numerous deer–human conflicts (VerCauteren 2003, Ng et al. 2008, Bissonette et al. 2008, DeNicola et al. 2008). For example, deer presence at airports has become more common (Bashore and Bellis 1982, Belant et al. 1998, Wright et al. 1998, DeVault et al. 2008). Deer are involved in 65% of aircraft–mammal strikes (Frankenfield et al. 1994). It is imperative to keep airports free of deer. Aircraft–deer collisions pose a serious risk to human welfare and are extremely expensive. As deer populations increase in areas surrounding airports and other areas where traditional population reduction methods, such as hunting, may not be acceptable or feasible, effective methods to exclude deer will be needed (Rutberg and Naugle 2008, Mastro et al. 2008). The existing fences around most airports can effectively exclude deer, but if gates are left open deer can gain access.

In addition to protecting public safety, excluding wildlife from specific areas may further efforts to eradicate disease (Hartin et al. 2007). In Michigan, for example, white-tailed deer act as a reservoir for reinfecting cattle herds with bovine tuberculosis (TB; Davidson and Nettles 1997). Approximately 35 cattle operations in Michigan have been infected (Michigan Bovine TB Eradication Project 2005) with the same strain of TB as identified in free-ranging deer (Dorn and Mertig 2005). Although direct contact between deer and cattle is rare (Hill 2005), infected deer may contaminate stored feed (Palmer et al. 2001, 2004). Cattle producers who wait for bovine TB to be eradicated from wildlife in the foreseeable future face disappointment because existing sociopolitical factors limit disease eradication efforts (O'Brien et al. 2006). Thus, producers need effective and practical means that they can implement to reduce the risk of bovine TB infecting their cattle.

Various management efforts have been implemented by state and federal agencies to reduce TB transmission, including increasing hunter harvest to reduce deer densities, restricting baiting and feeding, culling, fencing stored feed and areas where cattle are fed, depopulating infected cattle and captive cervid farms, and conducting research to develop nonlethal tools. One management effort by the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services (WS) involved the purchase and installation of 2.3-m woven-wire fencing around stored feed areas for cattle producers whose livestock was at risk of being infected. Wildlife Services constructed 54 exclosures to keep potentially TB-infected white-tailed deer from contaminating stored feed meant for cattle. A problem with exclosures is the inconvenience for producers to close the gates, which, if left open, could allow deer to access the area (West et al. 2007). Wildlife Services personnel often observe these gates being left open for extended periods (Butchko 2005). Means to easily allow access to vehicles and machinery while effectively preventing passage of deer are needed.

Researchers have been designing and evaluating alternatives to traditional gates for decades with mixed success. Reed et al. (1974) used modified cattle guards constructed of flat mill steel, with little success; 16 of 18 deer successfully crossed the guard. Belant et al. (1998) used a design with round tubing to successfully exclude >88% of deer, compared to pretreatment crossings. Peterson et al. (2003) evaluated 3 designs of deer guards and found bridge grating to be 99% effective at excluding Key deer (*Odcoileus virginianus clavium*). Seamans and Helon (2008) evaluated the use of experimental electrified mats as an alternative to gates and found them to be 95% effective.

Our objective was to evaluate efficacy of a modified deer guard and a mechanically activated, automatically reclosing gate for preventing deer entry into fenced exclosures. Such a device would not require electrical power and may provide convenient and effective means for excluding deer from fenced areas, ultimately reducing potential for deer to contaminate feed, lessen risk of collisions with aircraft and motor vehicles, and reduce crop damage.

Study area

We worked at 3 geographically distinct locations that were under state or federal management and had high densities of deer. Our easternmost site was within the 2,200-ha NASA Plum Brook Station (PBS), Ohio (41° 22′ 22″ N, 82° 40′ 56″ W). The site was enclosed by a 2.4-m-high, chain-link fence. Habitat within consisted of shrubland, grassland, open woodlands, and mixed hardwood forests. The estimated deer population during the study was 1,422 (65/km^2; T. Baranowski, U.S. Department of Agriculture, unpublished data).

The westernmost site was the 2,849-ha DeSoto National Wildlife Refuge (DNWR), located in eastern Nebraska and western Iowa (41° 31′ 27″ N, 96° 0′ 58″ W), which was comprised of bottomland forest, grassland, wetland, and agricultural fields. The estimated minimum deer population during the study was 722 (25/km^2; G. Clements, University of Nebraska–Lincoln, unpublished data).

Our northernmost site was Sandhill Wildlife Management Area (SWMA), which was comprised of 3,263 ha of deer range enclosed by a 2.7-m-high woven-wire fence, in central Wisconsin (44° 19′ 54″ N, 90° 9′ 53″ W). The habitat featured grassland; sandy uplands of oak, aspen, and jack pine; open woodlands; large marshes; and many flowages. The estimated minimum deer population during the study was 306 (9.4/km^2; W. Hall, Wisconsin Department of Natural Resources, unpublished data).

Methods

Experimental field evaluation

We established 6 experimental units at each of our 3 sites, consisting of square (6 m/side) exclosures constructed of deer-resistant fencing. At each site, we placed 3 exclosures in grassland and 3 in woodland habitats and allocated 1 exclosure per habitat type to each of 3 treatment levels: deer guard, gate, and control. All exclosures had a 3-m-wide opening centrally located in 1 side to accommodate deer guards and gates and to provide an unprotected opening in control units. For gated exclosures, we selected the flattest location without obstructions that might interfere with gate movement. We randomized allocation of control and deer-guard exclosures between

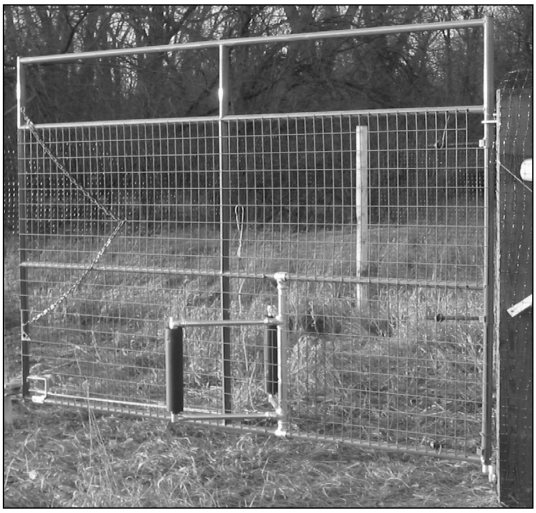

Figure 1. Deer gate equipped with a heavy-duty Bump Gate© kit at a deer exclosure at DeSoto National Wildlife Refuge, Iowa, USA.

the remaining 2 locations. We maintained a supply of alfalfa cubes (Canadian Bio-cube®, Kincardine Ontario, Can.) in the center of each exclosure to motivate deer to attempt entry into exclosures.

Bump Gates Australia (Childers, Queensland, Australia) makes hardware kits (Bump Gate©) that mount on tubular steel gates to allow vehicle activated opening and automatic closing. Low-speed (2 km/hr) vehicle contact with a rubber-sleeved release arm allows latch-spring compression and vehicle momentum to open the gate. The fully-open gate engages a delay catch that briefly holds the gate open. Gravitational force closes the gate after the catch releases. Bump Gate kits were designed for use with passenger cars and pickup trucks (not larger trucks or heavy equipment), and product literature (www.bumpgates.com) claims that closing speeds can be adjusted to accommodate such vehicles towing a trailer. We used commercially-available deer gates (Powder River, Provo, Ut.) measuring 2.4-m high × 3.0-m wide, made with 16-gauge, 41-mm diameter steel tubing and 8-gauge wire fill with opening dimensions of 50 mm × 101 mm (Figure 1). Gates had a mass of 50 kg before addition of Bump Gate hardware. We used the Bump Gates Australia Heavy Duty Timber Kit and followed manufacturer's installation instructions. The manufacturer claims that livestock rubbing or pushing against the bump arm cannot accidentally open gates properly equipped with Bump Gate kits (www.bumpgates.com). During the experimental phase of our study, we evaluated whether deer could breach gates. We later assessed the reliability of the system for securely closing gates after vehicle passage.

We also tested a modified cattle guard conceptually similar to that of Belant et al. (1998). Our prototype deer guard design consisted of roller conveyor sections installed over an excavated cavity where rollers were supported approximately flush with ground level and 0.4 m above the cavity floor. Panel dimensions were approximately 1 m parallel to roller axes × 1.5 m perpendicular to roller axes. We installed 3 panels side by side to create a 1.5-m × 3-m deer guard (Figure 2). We placed 48-mm-diameter rollers at 114-mm intervals, providing 66 mm openings between rollers. We hypothesized deer would be unwilling to walk across this guard because the cross members would roll beneath their hooves.

We attempted to maximize spacing between exclosures at each site to reduce interdependence on deer visitation and behavior among exclosures. Minimum spacing between control and treatment exclosures was 1.1 km at DNWR, 0.8 km at PBS, and 1.2 km SWMA ($\bar{x}$ = 2.3 km, 2.1 km, and 2.7 km, respectively). Minimum spacing among treatment exclosures was 0.6 km at DNWR, 0.8 km at PBS, and 0.7 km at SWMA ($\bar{x}$ = 1.6 km, 2.3 km, and 3.2 km, respectively). Spacing between control exclosures was 2 km at DNWR, 3.4 km at PBS, and 3.2 km at SWMA.

We installed 2 animal-activated, program-

Figure 2. Experimental deer guard installed at a deer exclosure at DeSoto National Wildlife Refuge, Iowa. The guard consisted of 3-roller conveyor panels suspended over a 400-mm-deep cavity. Guard dimensions were 1.5 m × 3 m.

mable digital cameras inside each exclosure to record the presence and activity of deer (Reconyx® Silent Image™, Reconyx, LLP, La Crosse, Wis.). We placed cameras in the back corners of exclosures, oriented so that each camera covered all of the opening and nearly all of the exclosure. We used redundant camera coverage to protect against camera malfunction and loss of data. We provided deer feed (alfalfa cubes) close to ground level and did not block the cameras' field of view. We programmed cameras to collect 60 photographs (burst) during 90 seconds following a trigger event and to retrigger immediately after a burst if animals were detected. We maintained camera monitoring from December 24, 2006, through April 12, 2007.

Supplemental Bump Gate function evaluation

Following our field study, we installed a Bump-Gate-equipped gate (one from the field study) at the National Wildlife Research Center in Fort Collins, Colorado, to evaluate functionality and reliability. We installed the gate in a north-south fence with hinge and latch at north and south ends of the gate, respectively. Our installation met or exceeded the manufacturer's standards. We welded the gate hinges to a 152-mm-diameter steel post. The post was set 0.8 m deep in concrete, and the concrete cured for 1 week prior to mounting the gate on it. Additionally, we set the lock post and delay catch posts ≥0.6 m deep in concrete and allowed for curing before testing. After making necessary adjustments to level the gate, and set delay catch and speed screw, we tested the mechanism during varied wind directions and speeds. We drove a Ford Ranger short-bed pickup back-and-forth through the gate on 7 dates from October 30, 2007, to January 16, 2008, and accumulated data on 235 deer passes through the gate. We recorded wind velocity (Kestrel 3000, Forestry Suppliers, Jackson, MS), wind direction, and whether the gate opened, closed, properly caught on the delay hook, or hit the vehicle while closing.

Analyses

We reviewed images from only 1 camera per exclosure and alternated cameras daily when both cameras were functional. If 1 camera was nonfunctional, we used imagery from the functional camera on successive days until both cameras were again functional. We reviewed camera images and counted deer inside the exclosure for each camera burst.

We took a paired-comparison approach to analysis, where protected exclosures were paired with unprotected exclosures within habitat type at each site. We structured our response variable as a difference in deer activity between unprotected and protected exclosures. Within sites, we used data from days when at least 1 camera was functional at each exclosure and computed a response variable as

$$\delta = \sum_{i=1}^{d} \frac{a_i}{d} - \sum_{i=1}^{d} \frac{b_i}{d} ,$$

where a_i = daily total count of deer per camera burst (events) inside unprotected exclosure, b_i = daily total count of events inside paired protected exclosure, and d = number of days when ≥1 camera was functional at each exclosure at a given site. We standardized δ to a daily basis because d varied among sites. We used general liner modeling (PROC GLIMMIX, SAS Institute 2006) to estimate δ as a function of fixed effects site and habitat, using maximum likelihood with a Gaussian distribution and identity link. We reported estimates of treatment effect (δ) and 95% confidence intervals (CI) for Bump Gates and deer guards.

For the supplemental evaluation of the Bump-Gate-equipped gate, we classified outcomes by 3 classes of wind velocity (0–10, >10.1–20, and >20.1–30 km/hr), 3 classes of wind direction (relative to direction of gate closure) labeled "against", "mixed", and "with". While the gate was closing toward the east, winds from 110–180° (azimuth) consistently opposed the gate (against), but winds from 181–250° consistently opposed the gate when closing toward the west. Similarly, winds from 290–360° and from 0–70° consistently assisted gate closure to the east and west, respectively. Winds from other directions both opposed and assisted gate closure during portions of the gate's closing arc. We estimated the proportion of trials where the gate opened on contact by a vehicle, closed and latched after vehicle passage, was caught and briefly held by the delay catch, and whether the gate struck the

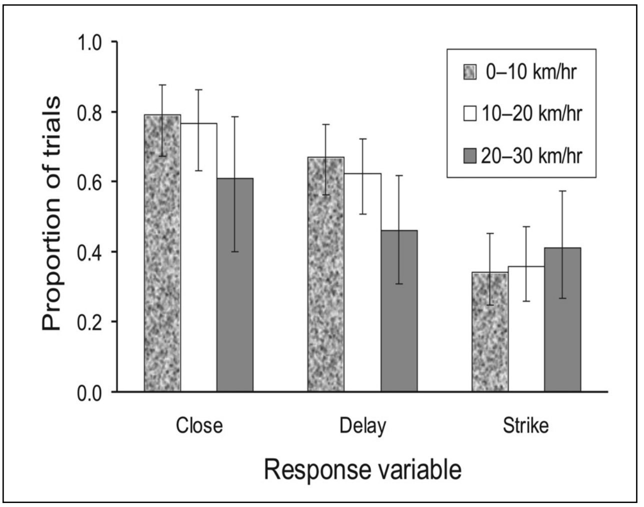

Figure 3. Results of supplemental evaluation of Bump-Gate-equipped deer gate from October 30, 2007, to January 16, 2008, in Fort Collins, Colorado, USA. Close = proportion of trials when the gate closed and latched properly. Delay = the delay catch caught and temporarily restrained gate from closing. Strike = the gate hit our vehicle during closing as a function of wind velocity classes. Error bars represent 95% confidence intervals.

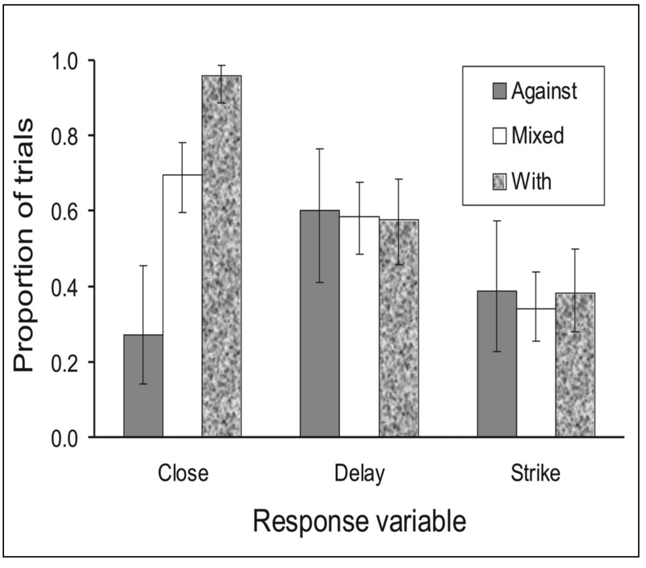

Figure 4. Results of supplemental evaluation of Bump-Gate-equipped deer gate from October 30, 2007, to January 16, 2008, in Fort Collins, Colorado, USA. Close = proportion of trials when the gate closed and latched properly. Delay = delay catch caught and temporarily restrained gate from closing. Strike = the gate hit our vehicle during closing, as a function of wind direction classes relative to gate closing direction. Against = trials when wind opposed gate closure throughout complete closing arc. With = wind assisted gate closure. Mixed = wind opposed and assisted gate closure during different portions of the closing arc. Error bars represent 95% confidence intervals.

vehicle during closing. We obtained maximum likelihood estimates of these proportions as functions of wind velocity and wind direction (fixed-effect predictor variables), and for pooled predictor variables (intercept only models) from generalized linear models using PROC GLIMMIX with the binomial distribution and logit link. We did not include wind velocity-by-direction interaction due to sparseness of data in some cells. In a post hoc evaluation, we estimated overall probability of vehicles being struck as a function of delay status (PROC GLIMMIX).

Results

We recorded no deer entry into exclosures protected by Bump Gates. We therefore excluded the Bump-Gate treatment level from modeling. The sites themselves had a strong effect on efficacy of deer guards ($F_{2,2}$ = 59.45, P = 0.02), but habitat type did not ($F_{1,2}$ = 0.07, P = 0.82), so we used a reduced model, including only site ($F_{2,3}$ = 86.30, P < 0.01) to estimate efficacy of deer guards. Deer guards nearly eliminated deer activity inside SWMA exclosures (δ = −48.9 events/day; 95%; CI: −57.6, −40.2; df = 3), where mean deer activity rate at control exclosures was the greatest among sites, at 49.0 events per day. Deer guards also were effective at DNWR exclosures (δ= −32.0 events per day; 95%; CI: −40.7, −23.3; df = 3), where mean deer activity rate at control exclosures was 33.0 events per day. We recorded no deer inside 1 DNWR exclosure protected by a deer guard. We also recorded no deer inside 1 deer guard exclosure at PBS, but a few deer became adept at jumping and walking across the deer guard at the other protected exclosure (2.5 events/day). Although deer density at PBS was the highest among our sites, mean deer activity at PBS control sites was low at 0.4 events per day and consequently we found no evidence of efficacy of deer guards at PBS (δ = 0.9 events per day; 95%; CI: −7.8, 9.5; df = 3). We also observed no injuries to deer due to jumping or walking across deer guards.

During supplemental evaluations, the Bump-Gate-equipped gate opened reliably every time we attempted to drive through it. However, we observed failure of the gate to close and latch, failure of the delay catch to temporarily restrain the gate from closing, and numerous occasions where the gate struck our vehicle. These problems were largely related to wind, although we found little evidence that wind velocity alone explained them (Figure 3). Wind direction, relative to gate closing direction, influenced probability of the gate closing and latching properly (Figure 4). The gate nearly always closed when assisted by wind (96%) and closed for 70% of trials when wind opposed and assisted gate closure during different portions of the closing arc, but closed for only 27% of trials when fully opposed by wind. Wind direction did not seem important in explaining function of the delay catch or probability of the gate striking our vehicle. The delay catch functioned properly in only 60% (CI: 54, 67; df = 234) of vehicle passages, and 35% (CI: 29, 42; df = 234) of all vehicle passages resulted in the gate striking our vehicle. Eighty-four percent (CI: 75, 90; df = 233) of delay-catch malfunctions resulted in strikes, but only 4% (CI: 1, 8; df = 233) of passages resulted in strikes when the delay functioned properly.

Discussion

Deer-resistant gates fitted with Bump-Gate hardware were completely effective in preventing deer from entering our exclosures. To evaluate functional reliability, we performed supplemental testing of 1 deer-resistant gate equipped with a Bump Gate kit, revealing that the delay catch frequently failed to capture and hold the gate open (causing the gate to hit our vehicle) and that the gate often failed to close and latch properly. The delay catch operates on a simple principle and is easily adjusted. However, despite repeated efforts, we were unable to adjust the mechanism so that it functioned reliably under varying wind conditions. Failure of the gate to close properly was strongly associated with wind blowing against the gate during closure. However, wind velocities during our evaluation were not severe; always ≤30 km/hr. The deer-resistant gate we used may have been more sensitive to effects of wind than gates intended for use with Bump Gate kits. The height of our gate and the presence of welded-wire mesh between frame elements probably caused greater drag for our gate than for typical tubular steel gates intended for livestock. Gates with a more open mesh and less wind resistance would likely work better with Bump Gate kits while also preventing access by deer. However, unless gates can be prevented from hitting vehicles during passage and close and latch properly, it is unlikely the Bump Gate kit would be considered by potential users. Additionally, a beef cow in the pen in which we did this supplemental evaluation learned to lean against the release arm to open the gate and exit the pen. Although a beef cow was able to open the gate, we think the odds of a deer leaning against the release arm and opening the gate to be extremely low.

Although we statistically demonstrated efficacy of our deer guards at 2 of 3 sites during the study, we doubt this design would provide long-term deterrence for deer. At least 1 deer at each site defeated a deer guard by week 4 at DNWR, week 6 at PBS, and week 11 at SWMA. At DNWR, we recorded no deer inside deer-guard exclosures between weeks 4 and 10, but we recorded deer entries into 1 deer-guard exclosure every week from week 10 to the end of the study (week 16). At SWMA, we recorded a few deer entries into each deer-guard exclosure in week 15, and entries in week 16 spiked to the greatest level we recorded at any exclosure during the study. At PBS, deer entries at one of the deer-guard exclosures were common throughout the last half of the study. It should be reiterated that the study occurred from December 24, 2006, through April 12, 2007. We chose this time period (winter) because deer were most food stressed and our bait provided high levels of motivation for deer to cross guards or circumvent Bump Gates.

We observed no injuries to deer as a result of deer walking or jumping across guards. Reed et al. (1974) observed 4 deer that fell through their deer guards; none of them was seriously injured. Belant et al. (1998) and Peterson et al. (2003) acknowledged that deer crossed their respective deer guard designs, but the authors never mention injuries to deer. We recognize that injuries could result to deer trying to walk or jump deer guards, but we feel the benefits of this tool for protecting human health and safety outweigh the risks to deer.

We photographed deer walking and jumping across deer guards. Of the events where the deer-guard crossing mode was identifiable, 83 deer were jumping and 19 were walking. Deer that walked across the guards found footing on compacted snow in the shallow pits under the rollers or on the flat bars between sets of rollers. We also believe more deer would acquire these behaviors over a longer evaluation period, thus reducing efficacy of the deer guards. Belant et al. (1998) tested cattle guards over excavations 0.5-m and 1-m deep. They state that in areas of moderate to high snowfall, increasing excavation depth and periodically removing snow from beneath guards should alleviate snow compaction by deer under guards. Our deer guards were positioned over 400-mm-deep excavations, which probably were not deep enough, given the amount of snowfall the study sites received. Reed et al. (1974) tested modified deer-cattle guards that were 3.7 m, 5.5 m, and 7.3 m long, with little success. The authors determined that guards >3.7 m long were no more effective than longer versions. Peterson et al. (2003) evaluated bridge grating with grate dimensions of 6.1 m × 6.1 m. They observed no Key deer jumping their deer-exclusion grates, but, rather, deer walked on the grate. Our deer guard could be made more practical and effective by increasing the crossing distance beyond that which a deer would jump, by eliminating the bar between roller sections, and by increasing the depth of the pit beneath the deer guard. Additionally, functional guards would need to be constructed more robustly to handle the weight of vehicles and to resist intrusion of dust and moisture into bearings.

Management implications

We evaluated the only commercially available bump gate kit that we could find. The gate effectively prevented access by deer, but because it did not function reliably we cannot recommend its use. However, we have seen homemade versions on large cattle ranches that would likely be as effective and reliable against deer. In addition, our experimental deer guard could be useful if used in conjunction with a traditional gate in a deer-proof perimeter fence. For example, if a gate at an airfield receives a lot of vehicle use during the work day, the gate could be left open so that only the guard is deterring deer. The rest of the day and night, when deer are more active, the gate could be closed to further prevent deer access. With some modifications both of the strategies we evaluated have the potential to become practical tools for keeping deer out of airports and stored feed areas, while allowing access to vehicles and heavy equipment.

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Michael J. Lavelle (left) is a wildlife biologist with the wildlife disease research program at the National Wildlife Research Center (NWRC). He received his B.S. degree in wildlife management from the University of Nebraska–Lincoln. His research interests focus on interactions of cervids and associated risk of disease transmission.

Justin W. Fischer (second from left) is a wildlife biologist and GIS specialist with the chronic wasting disease project and invasive species and technology development research program, both with the NWRC. He received his B.S. and M.S. degrees from the University of Nebraska–Lincoln. His research focuses on devising means to reduce chronic wasting disease transmission, spatial analysis using GIS and remote sensing techniques, and database design and maintenance.

Gregory E. Phillips (far right) is a wildlife biologist with the NWRC. He holds a B.S. degree in natural resources from the University of Michigan, an M.S. degree in wood science from Colorado State University, and a Ph.D. degree in wildlife biology from Colorado State University. He has conducted research to evaluate effects of human-induced disturbance on reproductive success of elk and behavior of mule deer, developed methods for quantifying avian fatalities associated with power line structures, and used stochastic modeling to evaluate effects of predator control on ungulate populations. His current position involves design and analysis of studies for investigating and managing interactions between domestic livestock and free-ranging ungulates. He is a former executive board member of the Colorado Chapter of The Wildlife Society.