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EFFECTIVENESS OF A WHITE-TAILED DEER EXCLUSION FENCE BASED ON TRACTION LIMITATIONS OF THE HOOF: THE SLIPPERY FENCE

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Abstract: We hypothesized that an exclusion fence could be devised to capitalize on traction limitations of the hooves of white-tailed deer (*Odocoileus virginianus*). Hexagonal plots (9.8 m wide) enclosed by a 2.4 m field fence with two openings (4.9 m) were established. Data were collected daily on consumption of corn provided (2.27 kg) and events recorded by infrared monitors (IR) for treatment and control sites. Five-day treatment periods consisted of test panels (4.9 m x 2.4 m) placed in plot openings at 0^o, 5^o and 10^o slopes, and lubricant applied at the 10^o slope. Deer consumed all corn provided at control sites. At the 10^o slope, daily corn consumption decreased (1.50 kg ± 0.26, $p < .01$), and IR events were lower ($p < .01$) at treatment sites (23.6 ± 3.2) compared to controls (50.3 ± 9.6). With the addition of a lubricant, corn consumption decreased further ($p < .001$) to 0.17 kg ± 0.03, and IR recorded events were lower ($p < .001$) at treatment sites (6.58 ± 0.89) compared to controls (44.8 ± 3.1). Results of this study indicate that traction limitation of the hoof can be exploited.

Key words: exclusion fence, hoof characteristics, white-tailed deer

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INTRODUCTION

The development of exclusionary methods to reduce deer damage is well documented. Efforts to control white-tailed deer movement have been difficult because these animals are capable of jumping 3 m fences and fitting through spaces < 20 cm (Vercauteren and Lavelle 2003). Numerous systems have been based on modifications of electric fences designed for livestock including: seven-wire strand vertical (Palmer et al. 1985, Craven and Hygnstrom 1994), electric polytape (Owen et al. 1995), two-wire outrigger (Scott and Townsend 1985, Howard 1991), slanted fences (Craven and Hygnstrom 1994), and double offset fencing (Fitzwater 1972, Palmer et al. 1985, Craven and Hygnstrom 1994). Electric fencing systems exhibit varying degrees of effectiveness and tend to be low cost, but are prone to short-circuiting and may require extensive maintenance (Porter 1983, Craven and Hygnstrom 1994). Chain link fences (Bashore and Bellis 1982) and woven wire fencing (Nolte 1999) greater than 2.4 m in height have been reported to be effective. Vercauteren and Lavelle (2003) suggest a 3.0-3.6 m wire mesh fence can be nearly impenetrable. These types of fencing materials are reported to be more effective but tend to be expensive and often cost prohibitive (Nolte 1999). Recent efforts to evaluate the effectiveness of a perceived solid barrier (1.7 m) made of cloth were found to be extremely effective as a deer exclosure (Gallagher et al. 2003).

Evaluation of horizontal based exclusion methods has been limited. Traditional cattle guards and similar structures have been examined with varying degrees of success (Reed et al. 1974, Belant et al. 1998). Peterson et al (2003) evaluated deer-exclusion grates consisting of triangular and rectangular patterns, reporting significant success with triangular shaped patterns on steel grates.

We approached the problem based on the basic anatomy and physiology of the white-tailed deer hoof. The two-toed ungulate hoof type is designed to provide traction on a number of natural surfaces. While being ideal for locomotion in most situations, this anatomical feature has limited effectiveness on slippery surfaces, natural or manmade. Therefore, the purpose of this project was to evaluate the effectiveness of an horizontal based fence system designed to exclude white-tailed deer based on tactile and traction characteristics of the hoof.

MATERIALS AND METHODS

Study Area

This study was conducted on the 1,215 ha wildlife refuge area encompassing the Berry College campus in Northwest Georgia. Deer population in the refuge area was estimated as 1 deer per 4 ha (T. Touchstone, Georgia Department of Natural Resources, personal communication).

Plot Design

Three plots were constructed in established Bermuda (*Cynodon spp*.) hay fields and Fescue (*Festuca arundinacea*) pastures utilized for livestock. Plots were designed to provide a visual perception of openness from the entrances located at each end, with minimal opportunity to enter each fenced area from locations other than the designated entrances. Treatment areas consisted of hexagonal plots approximately 9.8 m wide, enclosed by a 2.4 m field fence with two, 4.9 m openings on opposite ends. A 2.4 m field fence was also erected on both sides of each opening extending 2.4 m away from the hexagonal pens. Feed stations were constructed within the center of each plot by placing a plastic tray (42 x 43 x 10 cm) on a single layer of cinder blocks and securing the tray by driving steel rods in the ground around the perimeter. An infrared game monitor (Trail Timer®, Plus 500, St. Paul, MN 55128) was secured to a fence post at a height of 1 m and positioned perpendicular to the openings, approximately 4.8 m from the feeder within each hexagonal plot.

Control plots were established adjacent to each fenced area. Infrared game monitors were secured at a height of 1 m to a post approximately 9.8 m away from the hexagonal exclosure. Feed stations were centrally located between the post with the infrared monitor and the perimeter of each hexagonal exclosure. Infrared game monitors for control and treatment areas were facing each other in an attempt to approximate similar distances for recording animal activity with respective control and treatment areas. In order to minimize monitors from recording activity beyond the respective control and treatment areas of each plot, a 2 m x 2 m screen of two layers of 10 oz burlap was secured to the fence between the control and treatment infrared monitors.

The test surface (4.9 m x 2.4 m) was constructed of conventional 5-rib tin panels, typically utilized as a roofing material, mounted to a framework of 2.54 cm x 5.08 cm boards.

Experimental Protocol

A preconditioning period was conducted to allow deer to become accustomed to entering and feeding from exclosures. Preconditioning was considered complete when deer consumed all feed provided at all control and treatment feeders for a period over five consecutive days. Following preconditioning, all subsequent treatment periods were 5 days. Tin panels were initially secured into the openings of each treatment enclosure, level (0^o) to the ground. In subsequent treatment periods, the end of the panels toward the interior of the hexagon exclosures was raised to a 5^o slope followed by a 10^o slope. For the final three, 5-day treatment periods, the panels remained at the 10^o slope and a lubricant was applied to the test surfaces.

Data Collection

Corn (2.27 kg) was provided daily within treatment and control feeders at each plot between 1500 h and 1600 h. Consumption of corn provided the previous day was recorded. Any uneaten corn was discarded. Activity from the previous 24-hour period, as determined by infrared game monitors, was also recorded.

Visual observations of deer activity occurred for a 2-hour period on the fourth day of each treatment period immediately following daily data collection. Behavioral data were collected by observers in vehicles at consistent locations approximately 100 m – 300 m from each plot. Survey flags placed 3.0 m beyond the outer edges of each test surface panel served as the observation area. Final outcomes of deer entering this 4.9 m x 2.4 m area were recorded. Deer responses were classified into one of four behavioral categories. Animals that walked through the 4.9 m x 2.4 m sample area and presented no discernable interest in facing or crossing the test surface were classified as ignoring the entrance. Deer that faced the test panel, but made no contact with the hooves on the test panel were place in a Faced/No contact category. The Faced/Contact classification included animals that made contact with the test panel with hooves and either abandoned the attempt to enter the exclosure or failed in the attempt and retreated. Deer that successfully crossed the test panel were recorded as Crossed.

Static friction coefficients (μ) of the tin surface were derived by determining the force required to move a 454 g circular steel weight as measured by a 300 g precision scale (Pesola®, Baar, Switzerland). Five replicates were used to determine the relative static friction for the steel disc on the tin panels at 0^o, 5^o, 10^o slope as well as with different lubricants. Lubricants examined were Armor-All® (The Clorox Co., Oakland, CA 94612), Camp Dry® (Kiwi Brands Douglasville, PA 19518), Liquid Gold® (Scott's Liquid Gold, Denver, CO 80239) and WD-40® (WD-40 Co. San Diego CA 92110). One lubricant (WD-40®) was selected for use in this study based on the low friction coefficient observed, ease of application and availability of the product in a liquid form. Following the initial 10^o slope treatment, WD-40® was applied to the test surface using a conventional pump operated spray bottle. Reapplication of the lubricant occurred on day 0 for each of three 5-day treatment periods.

Statistical Analysis

Statistical analysis of all data was completed utilizing SPSS, version 12.0.1 (2003). Multivariate analysis of variance procedures were utilized to determine differences between treatments and plots as fixed effects with corn consumption and events recorded by the infrared monitors as dependent variables. Paired T-test was used to determine differences in corn consumption and infrared monitor events recorded between treatment and control sites within treatment period. Differences in friction coefficients among lubricants were examined by one-way analysis of variance and Duncan's Multiple Range test. Behavioral observations are presented as frequency and proportions of those frequencies based on the activity of any deer observed within the designated area across all plots during the 2-hour observation period.

RESULTS

Friction coefficients of steel on tin determined in this study were similar to those reported in the literature (Grigoriev and Meilikhov 1997). As expected, static friction coefficients decreased with the increase in slope and application of lubricants (Table 1). Based on these values, application of the lubricant was not utilized until after completion of the initial 10^o slope treatment period.

Table 1. Static friction coefficients (μ) of steel on clean tin panel test surfaces at different slopes and lubricant additions.

	Treatment				
Slope	Control	WD-40®	Camp-Dry®	Armor All®	Liquid Gold®
0^o	.54 ± 0.02^d	.31 ± 0.01^b	.23 ± 0.01^a	.30 ± 0.22^b	.40 ± 0.01^c
5^o	.27 ± 0.01^d	.19 ± 0.01^b	.17 ± 0.01^a	.21 ± 0.01^b	.24 ± 0.01^c
10^o	.15 ± 0.01^{bc}	.08 ± 0.01^a	.06 ± 0.01^a	.17 ± 0.01^c	.12 ± 0.01^b

^{abcd} Values with different superscripts in each row differ (P<.05).

Deer consumed virtually all of the 2.27 kg of corn provided daily at control and treatment feeders during the pre-treatment and when test surfaces were incorporated at both the 0^o and 5^o slope (Figure 1). While deer continued to consume all corn provided at control feeders (2.27 kg ± 0.00) throughout the remainder of the study, consumption within the treatment areas decreased (p<.01) when the test surface was raised to the 10^o slope. During the next three 5-day periods, application of the lubricant to the test surface maintained at the 10^o slope reduced (p<.001) corn consumption to near negligible amounts (0.17 kg ± 0.04).

Deer activity recorded as events by the infrared game monitors provided an indication of relative activity at respective control and treatment sites (Figure 2). Recorded events followed a similar trend as consumption of corn. Events recorded at treatment and control sites were similar during the pre-treatment, and when test surfaces were at both the 0^o and 5^o slope. The number of events recorded at treatment locations was lower (50.53 ± 9.57); p<.01) when the test surface was at the 10^o slope compared to controls (23.60 ± 3.16). When lubricant was added to the test surfaces, recorded events were further reduced (p<.001).

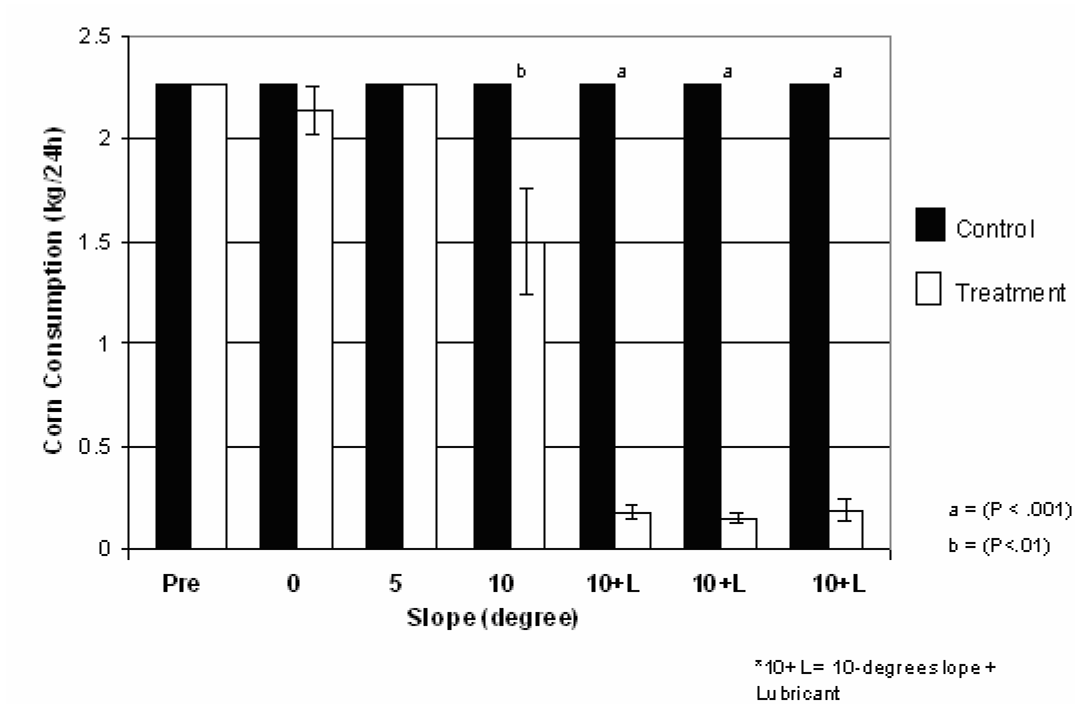

Figure 1. Average daily consumption of provided corn (2.27 kg) by white-tailed deer for each 5-day treatment period.

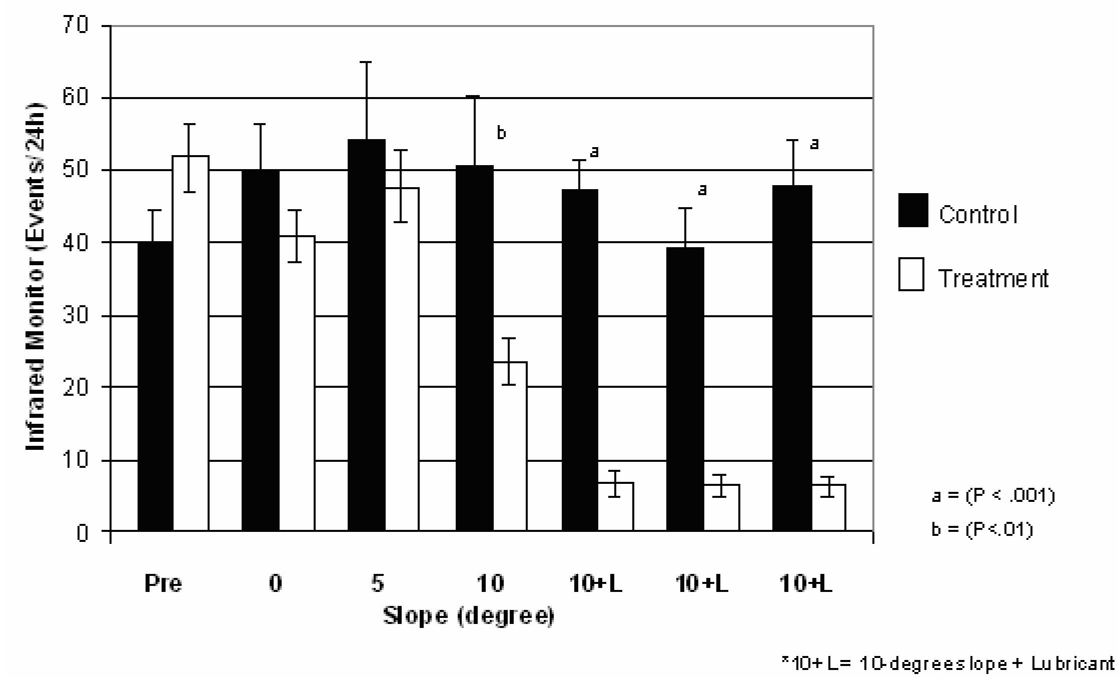

Figure 2. Average daily events of white-tailed deer activity recorded by infrared monitors for each 5-day treatment period.

Behavioral observations of white-tailed deer were recorded during a 2-hour period Immediately following the daily data collection and replacement of corn on the fourth day of each 5-day treatment period (Table 2). Behavioral observations presented include the final outcome of what was observed once an animal entered the designated 4.9 m x 2.4 m area immediately in front of the test panel surfaces. Across all treatment periods, the most frequent observations recorded were deer showing no interest (ignored) when entering and subsequently leaving the 4.9 m x 2.4 m area in front of the test surface. During the periods where the slope of the test panels was at 0^{o}, 5^{o} and 10^{o}, deer were also observed facing the panel with no attempt to cross or physically contacting the test surface then aborting the attempt. Deer that crossed the panels tended to show little reluctance when initially contacting the panel, but did provide evidence that the surface was slippery. Deer tended to take very short deliberate steps with the head level or below the height of the shoulders. Once the lubricant was added to the surface of the test panels, no deer were observed entering the enclosures. Although the width of the panels was 2.4 m, no deer were ever observed jumping the panels to enter the exclosure.

Table 2. Behavioral observation outcomes of white-tailed deer interactions with the test surfaces recorded during a 2-hour post-feeding period across treatments.

Slope[a]	N[b]	Behavior[c]	Frequency	%
0^{o}	57	Ignore	24	42.1
		Faced/No contact	13	22.8
		Crossed	20	35.1
5^{o}	72	Ignore	24	33.3
		Faced/No contact	14	19.4
		Faced/Contact	13	18.0
		Crossed	21	29.2
10^{o}	62	Ignore	24	38.7
		Faced/No contact	8	12.9
		Faced/Contact	17	27.4
		Crossed	13	21.0
10^{o} +L	12	Ignore	8	66.7
		Faced/No contact	4	33.3
10^{o} +L	14	Ignore	9	66.7
		Faced/No contact	5	35.7
10^{o} +L	5	Ignore	4	80.0
		Faced/No contact	1	20.0

[a] 10^{o}+ L = 10^{o} slope + application of additional lubricant
[b] Number of observations recorded within the 4.9 m x 3.0 m defined area in front of the test surfaces
[c] Behavioral Codes
Ignore – Animal walked through the 4.9 m x 3.0 m sample area and presented no discernable interest in crossing the test surface.
Faced/No contact – Animal faced the test panel, but made no contact with the hooves on the test panel
Faced/Contact – Animal faced and made contact with the test panel with hooves but did not attempt to cross or abandoned the attempt to enter the exclosure
Crossed – Animal successfully crossed the test panel and entered the exclosure

DISCUSSION

Results of this study clearly indicate the concept of a horizontal based fence system based on tactile and traction characteristics of the hoof has potential to control the movement of white-tailed deer. Concerns we had related to the natural reflective color of the tin and the sound resulting when a deer contacted the panel with the hoof appeared not to be a factor. In this study, consumption of corn was reduced by 34% once the test panels were raised to create a 10^{o} slope. This aspect is highly significant considering only 2.27 kg of corn were provided daily. Once an additional lubricant was added to the test panels, daily corn consumption was reduced to negligible levels. Small birds were often seen feeding on corn at the feed stations and were the likely cause of the limited amounts of corn consumed during these time periods. Field and Song sparrows were also documented feeding on corn in a previous study using similar feed stations (Gallagher et al. 2003).

While events recorded by the infrared monitors dropped significantly during the last three treatment periods, 10^{o} slope plus additional lubricant, they were higher in one plot than would be expected. During these treatment periods events recorded in plot 1 averaged 13.8 ±1.84 events per day compared to plot 2 (2.13 ± 0.13 events/day) and plot 3 (3.8 ± 0.83 events/day). Typically, the infrared monitors inherently record two events during normal operations without the presence of an animal large enough to trigger the system. As previously indicated, infrared game monitors for control and treatment areas were facing each other in an attempt to approximate similar distances for recording animal activity with respective control and treatment areas. The higher level of activity recorded in plot 1 was likely due to failure in the burlap material as a result of deterioration and damage that occurred during the course of this study. Regardless, events recorded by the infrared monitor support the effectiveness of the methodology tested.

Behavioral observations provided insight to deer activity when encountering the test surfaces. The most frequent observations recorded were deer showing no interest when entering and subsequently leaving the 4.9 m x 2.4 m area in front of the test surface. We postulate that some of these animals had become conditioned to ignore the test panels based on failed attempts that occurred during the previous 3 days of exposure to that treatment. As a general trend, while deer activity in the area remained consistent, the number of deer approaching the test surface panels as well as attempting to cross or successfully crossing the surface decreased as the friction coefficient decreased during progressive treatment periods. Despite the slopes and the addition of lubricants, there was no difficulty or slipping encountered when humans crossed the test surfaces.

Of particular interest was that at no time was a deer observed jumping across the test panel to enter the enclosures. While it is certainly presumed that deer should be capable of jumping the relatively short distance (2.4 m), the literature is virtually devoid of information beyond anecdotal evidence. Deer leaving the exclosures at the 0^{o} slope walked across the panel. However, at the 5^{o} and 10^{o} slope all deer observed entered the exclosure by walking, but exited by jumping the panel. The result of incorporating the slope may have provided a visual perception illusion that influenced their behavior and warrants further investigation.

We utilized slope and lubricant with the intent of decreasing the friction coefficient to make the surface more slippery. While a friction coefficient of μ 0.08 was achieved by addition of the lubricant to the panels at a 10° slope, other substances could be more effective in achieving desired results. For example, the friction coefficient for Teflon® on steel at 0° slope has been reported to be μ 0.04 (Serway 1996).

Results of this study warrant further research into the concept of utilizing a slippery surface as a physical barrier. While effective in preventing deer from entering the enclosures, the surfaces posed no safety problems for humans crossing the test panels. Examination of a more suitable material and other lubricants could result in the development of a cost effective barrier.

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