EVALUATION OF DEER GUARDS FOR KEY DEER, BIG PINE KEY FLORIDA

Final Report

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ABSTRACT

Design and Evaluation of Deer Guards

for Florida Key Deer.

(May 2000)

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Because of increased deer/vehicle collisions involving endangered Florida Key deer (*Odocoileus virginianus clavium*), the Florida Department of Transportation (FDOT) developed a plan to construct a fence along a portion of US Highway 1 that crosses Big Pine Key, Florida. A problem associated with this plan involved access points where small public roads bisect US-1, which would allow deer to enter the fenced portion of the highway. Currently there are no structures (deer guard) that are effective in preventing deer from entering access roads. The purpose of this study was to design, construct, and test a deer guard that would allow normal passage of vehicles while preventing Key deer from crossing.

Between September 1998 and December 1999, deer guard prototypes were constructed and tested within a deer-holding facility at the Welder Wildlife Foundation Refuge near Sinton, Texas. Wild-trapped Texas white-tailed deer (*O. v. tenanus*) were used as test animals.

Deer-guard prototypes were subjected to 4 tests: (1) no incentive to cross; (2) extra food and water incentive to cross; (3) fawn separated from doe; and, (4) estrous doe separated from mature buck. Three deer guard designs tested included: (1) a guard installed at ground level; (2) a guard raised off the ground; and, (3) a raised guard with sloped ends. Deer guards were tested at 2 lengths (either 3.6 m or 5.5 m) and had 1.9 cm cross-member spacing. Effectiveness was monitored visually and/or with infrared triggered camera systems. All tests were conducted for 2 weeks except the fawn separated from doe tests (2 hours). Tests were replicated 4 times except the buck/doe separation test, which was replicated only twice.

No deer crossed a raised 5.5-m guard during any of the tests. It is recommended that FDOT construct and install deer guards measuring at least 7.3 m with the center portion raised 0.6 m above the ground. Ends should be sloped to facilitate vehicular traffic and cross-member spacing should be 1.9 cm or more. Side panels should extend the length of both sides of the guard. With slight modifications, the design should be useful with other species.

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INTRODUCTION

Reducing the impact of highway mortality on Florida Key deer (*Odocoileus virginianus clavium*) has been a major aspect of Key deer management in recent years. An increase in deer/vehicle collisions on Big Pine Key, Florida has created concern among wildlife biologists and conservation related groups.

High fencing of roadways, in conjunction with wildlife crossings, has been used to help reduce highway related deer deaths. Management of deer access into fenced roadways has been an unresolved issue, with no viable control available. Development of a structure (deer guard) that prevents Key deer access to fenced roadways while allowing vehicular traffic would be a valuable tool in reducing occurrences of deer/vehicle collisions. There are currently no effective deer guard designs available for use on white-tailed deer (*O. virginianus*).

The purpose of this study was to design and test the effectiveness of deer guards for use on Florida Key deer. Development of deer guards is based on the need for prevention of deer accessing certain areas, such as: roadways or other sites that pose a particular hazard while allowing public vehicular access. The goal of this study was to determine the best possible deer guard design for use in the final phase of the SR-5/US-1 Key deer/Motorist Conflict Study (Project No. 2505641). This project was developed by the Florida Department of Transportation to reduce highway mortality of Key deer. Additional information derived from this study may be incorporated into applications for other species.

The format and style follow the Journal of Wildlife Management.

JUSTIFICATION

Key Deer Biology

Florida Key deer is the smallest subspecies of white-tailed deer. It is considered a unique subspecies based on its geographic isolation from white-tailed deer residing on the peninsula of mainland Florida. The average Key deer measures approximately 61-81 cm at the shoulder. Adult female Key deer weigh on average between 20-30 kg, while their male counterpart averages 25-36 kg. The breeding season of Key deer generally begins in September, peaks in early October, and runs through December. Bucks lose their antlers in February-March and the yearly growth cycle of new antlers is usually complete by August. Gestation period of Key deer is 204 days and fawns are usually born from April-June. At birth the average Key deer will weigh .9-1.8 kg (USFWS 1997). Key deer have been observed jumping a linear distance of over 9 m (N. J. Silvy, Texas A&M University, unpublished data).

Deer Numbers

Due to habitat destruction and unregulated hunting, Key deer numbers crashed to approximately 25-50 animals in existence by the 1950's (Dickson 1955). This downward spiral in Key deer numbers was halted by the development of the Key deer National Refuge in 1957. Stringent law enforcement efforts to protect Key deer were reinforced by the listing of the deer as an endangered species in 1967 (Folk 1991). Although limited in native habitat and range, the number of Key deer increased from an estimated 50 animals in the 1940's to approximately 300 animals in 1970.

Current estimates have placed the number of Key deer at over 600 animals (R. Lopez, Texas A&M University, unpublished data).

Key Deer Mortality

Although natural predation of Key deer is rare and hunting has been illegal for many years, Key deer are still experiencing unnatural mortality within their limited range. Highway mortality has been the most common cause of death of Key deer (Klimstra et al. 1982), along with occasional deaths due to drowning, disease, and parasites. An increase in deer populations and urbanization has facilitated this deadly interaction. From 1989-1995 there were approximately 45 Key deer killed each year on roadways. In the years 1996-1999 the number of Key deer highway mortalities has increased (Fig. 1). A record high of 88 Key deer were killed on roadways in 1998 and an additional 78 animals were hit and killed in 1999 (USFWS 1999). The Florida Department of Transportation (FDOT) has recognized an undeveloped stretch of US-1 that traverses through Big Pine Key, Florida as a problem area for deer/vehicle collisions (Fig. 2). This stretch of highway accounts for about half of the mean (44 deer) road-kills on this key. The FDOT District Six Environmental Management Office has developed a plan to help reduce the number of deer/vehicle collisions along this section of US-1. The plan involves the use of parallel high fences, which should prevent deer from entering the roadway. In conjunction with the high fences, wildlife crossings or underpasses will be installed to allow normal travel between habitats surrounding the highway. An underlying problem associated with this plan is public roads intersecting US-1, which could allow deer to enter fenced portions of the highway.

Residents of nearby neighborhoods, fishing camps and tourists use these access roads. This could be facilitated using a structure that would allow normal passage of vehicular traffic, while preventing deer from crossing (e.g. deer guards). Currently there are no deer guard designs that are effective at preventing deer access.

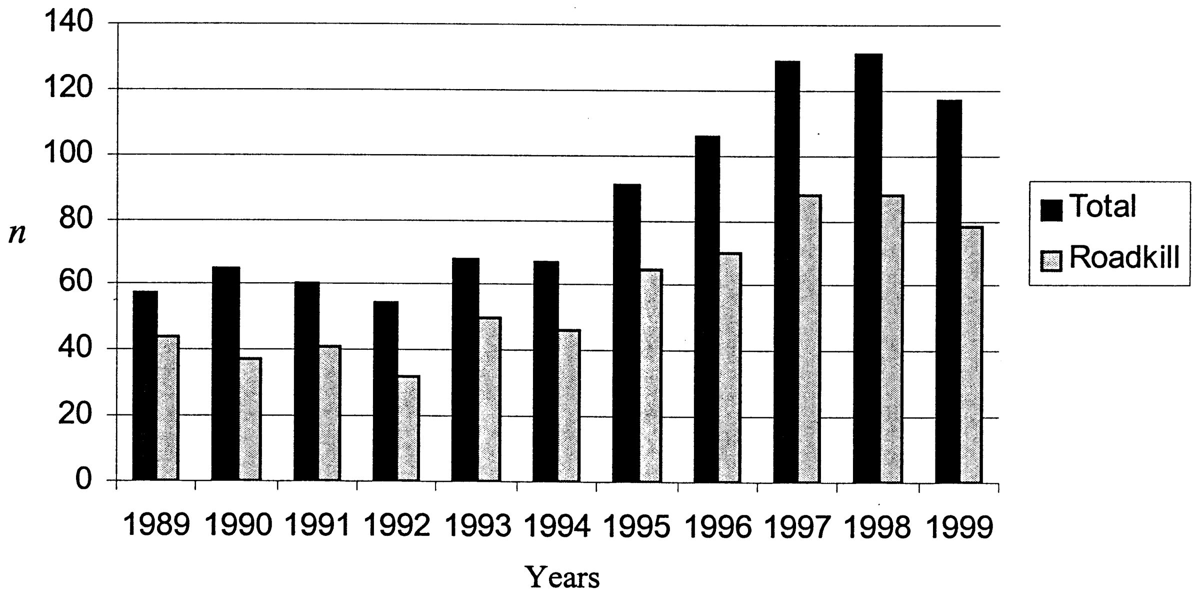

Fig. 1. Comparison of total mortality and road mortality (*n*) of Florida Key deer on Big Pine Key, Florida from 1989-1999.

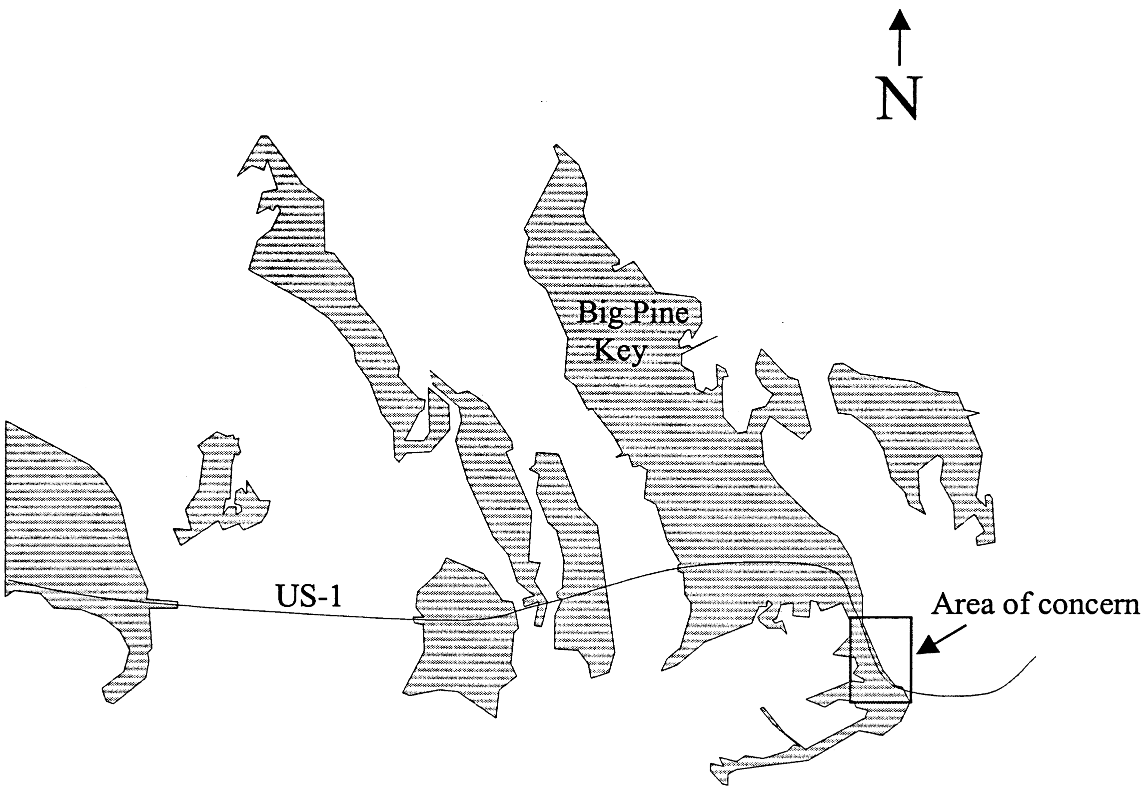

Fig. 2. Big Pine and surrounding keys with proposed high fenced stretch of US-1.

LITERATURE REVIEW

Increased expansion of urban areas also increases the possibility of wildlife/human conflicts and interactions. Interactions between humans and white-tailed deer have increased in North America, particularly in urban areas expanding into forests and parklands (Decker et al. 1987). Many human/wildlife conflicts and interactions occur on highways. Construction of highways and right-of-ways often create artificial edges through disturbance or removal of naturally occurring vegetation. These edges are often beneficial and attractive to many wildlife species (Leedy 1975a).

Deer Highway Use

Mammals use roadsides for various reasons such as feeding, nesting, and hiding cover. White-tailed deer have been known to frequent roadways in northern states where the practice of salting road surfaces is common (Dalke 1965) and in more temperate regions during spring green-ups (Bellis and Graves 1971, Puglisi et al. 1974). With so many different animals frequenting roadsides and highways, it is understandable that they are susceptible to vehicle-related mortality.

Damage Caused by Deer/Vehicle Collisions

Highway mortality of wildlife has been extensively researched, but estimating numbers of animals killed is variable. Although high in overall numbers, it is probable that road mortalities are not significant for most species, except endangered or protected species (Leedy 1975a). Conover et al. (1995) estimated that approximately 1.5 million white-tailed deer were killed annually on roadways, creating an average vehicle repair cost of $1,500 per deer/vehicle collision. Highway mortality of wildlife is often not the only loss of life in a deer/vehicle collision. Conover et al. (1995) estimated 29,000 people are injured each year in the United States in these accidents, and about 211 are killed. A combination of automobile damage, human safety, and concerns for wildlife have encouraged development of techniques to reduce numbers of animals that are being hit on roadways.

Methods of Reducing Highway Mortality

Signage.--One technique that has been used to reduce wildlife/vehicle collisions is wildlife crossing signage. Signs have been used on public roadways to warn motorists of deer crossings in high deer density regions. Effectiveness of conventional signs is probably limited because they are left in place all year, resulting in motorist habituation to them (Williams 1964). A study in Colorado evaluated the effect of displaying a lighted, animated sign warning motorists of deer crossings (Pojar et al. 1975). They concluded that lighted signs did not reduce the number of deer/vehicle collisions.

Lighting.-- An alternative method for reducing road-kills is installation of lights along highways. In a Colorado study, lights were installed along a section of heavily traveled highway to test their effectiveness of deterring deer (Pojar et al. 1973). Highway mortality of deer actually increased during the study, as compared to the previous 2 years. Reed (1981b) used mercury-vapor lamps along highways and measured deer-vehicle accident rates. Under lighted and unlighted conditions similar results were obtained.

Reflectors.--Reflectors and mirrors have been used along roadways to deter wildlife from these hazardous areas with varied results. A study in Michigan reported inconsistent results using mirrors as a means of reducing deer/vehicle collisions (Queal 1968). Gilbert (1982) observed mirrors had no effect on road-kill frequency. It has been speculated that animals become habituated to mirrors and reflectors and eventually pay them no attention (Beaucham 1970). In one controlled experiment, Swareflex reflectors were shown to be effective but are still considered to be of little use in preventing highway mortality of deer (Shafer and Penland 1985). During 1981-82, a 2-km segment along U.S. 1 on Big Pine Key posted with Swareflex reflectors failed to reduce road-kills. This was attributed to: interference from commercial lighting, vehicles knocked them down, and Key deer habituated to them. The high cost of maintenance resulted in their removal (Drummond 1987).

Deer Whistles.-- Some methods of reducing highway mortalities of wildlife have involved modifications or attachable accessories to motor vehicles. Commercially marketed deer whistles have been shown to have little effect on preventing deer from entering roadways. Romin and Dalton (1992) did not detect any differences in responses from mule deer (*O. hemionus*) to a vehicle mounted with and without Game Tracker's or Sav-a-life's wildlife warning whistles.

Deer-proof Fencing.--Placing game resistant fencing along highways has been used with some success in reducing vehicle-related mortality of wildlife (Woodard 1973). Most research in which this technique was used has involved ungulates. It has proven to be effective in reducing deer-vehicle collisions (Bellis and Graves 1971, Falk et al. 1978, Reed et al. 1982). A Colorado study involving mule deer demonstrated an annual deer kill reduction of 61% using a 2.4 m fence along a 1.8 km stretch of heavily traveled highway (Reed et al. 1975). Bashore et al. (1985) concluded that fencing was the cheapest and most effective means of preventing collisions and they recommended the use of fencing in high-kill areas along short sections of highway. Fencing is often used in conjunction with other methods such as highway overpasses or underpasses, and one-way gates.

One-way Gates.--One-way gates, when located strategically, were effective in allowing deer to escape from highway rights-of way (Reed et al. 1974a). However, Ford (1980) reported that one-way gates had limited effectiveness. Of 7 deer reported on the highway, 5 were killed and 2 were assumed to have escaped through gates.

Wildlife Overpasses/Underpasses.--Wildlife crossings (i.e. overpasses/underpasses) have been studied extensively as a means of reducing wildlife/vehicle collisions (Reed et al. 1981a). They are often used in conjunction with fenced roadways to allow movements of wildlife over, or under roads. Kuennen (1989) reported on the use of 2 (30.5 m) overpasses built for deer, as a path over an 8.9-km, 6-laned "sunken" highway. The overpasses were bordered with earthen berms and heavily landscaped with native shrubs and trees. Two years later, white-tailed deer were using the overpasses regularly for travel, foraging, and antler-rubbing. Highway underpasses have potential for reducing animal-vehicle accidents by providing a means for deer to pass under the highway (Leedy 1975b). Most successful installations of wildlife underpasses have placed crossing structures in or near traditional wildlife paths (Foster and Humphrey 1992). Ford (1980) and Ward et al. (1990) found deer used underpasses placed about 1.6-km apart. Effective underpasses have been as narrow as about 12.2 m at bridge level and 6 m at ground level (Ford 1980). Structures preventing deer from entering fenced portions of highways are another tool used in conjunction with, one-way gates, and wildlife crossings (Leedy 1975a).

Deer Guards.--Little work has been published concerning effective deer guards. Installation of cattle guards as a barrier to deer movement has been ineffective (Reed et al. 1974b). Reed et al. (1979) reported on 5 prototypes of deer guards and found none were effective. These prototypes were tested on mule deer in Colorado. Reed et al. (1979) installed 2 guards (3.0 x 3.7 m) constructed of flat mill steel 1.3 x 10.2 x 304.8 cm (width, height, and length, respectively) with the rails running perpendicular to the direction of travel. Rails were placed 10.2 cm apart. Three different lengths of guards were tested (3.7, 5.5, and 7.3 m). Lengths were measured parallel to the direction of travel. To test the effect of guard length on whether deer would cross, mule deer were released from crates into a pen with a deer guard as their only means of escape. Sixteen of the 18 deer used in this test made it across the guard regardless of length. Deer were able to walk across the guards by placing the tips of their hooves on 1 rail and their dewclaws on the preceding rail. Some deer fell through but were able to regain their footing by rolling on their sides and standing back up. Effectiveness of the deer guards was tested in the field by observing tracks leading up to the structure, and scuff marks made by hooves on the guard rails. Observations at the 2 test sites indicated that collectively 15 deer crossed and at least 11 did not. None of the animals jumped completely across any of the guards, regardless of length.

Since no scientific publications supporting use of deer guards for white-tailed deer were available, we based our original design on the Reed et al. (1974) mule deer guard.

METHODS

Study Site

Research was conducted at the Welder Wildlife Foundation Refuge in San Patricio County, near Sinton, Texas. A previously constructed deer facility, under a scientific research permit (SPR-0290-004) held by the Welder Wildlife Foundation and issued by Texas Parks and Wildlife, was available at the Refuge.

The deer facility consisted of 8 holding pens; 2 rows (A and B), each with 4 individual pens separated by cross fencing (Fig. 3). Exterior and interior cross fences were covered with black nylon material to prevent deer from seeing objects beyond the fences and to minimize outside distractions or disturbances. The 2 rows of pens were separated by a 5.5-m wide walkway. Individual pens could be accessed via the walkway through 0.9-m wide gates. The walkway allowed researchers to move from pen to pen without disturbing deer. Individual holding pens were approximately 24 x 24 m and had gates (0.9 m) between individual pens within rows that allowed deer to move between pens. Exterior fences were 2.7 m in height and interior cross fences were 2.5 m in height. All fences were constructed of 12.7-cm square mesh galvanized fencing material supported by 5-cm welded drill stem pipe and creosote treated telephone poles.

Test Animals

Wild-caught, Texas white-tailed deer were already available in the holding pens. These deer were trapped in May 1998 and had been used by Texas Tech University for another research project. On 1 September 1998, the deer and research facility was turned over to Texas A&M University. Deer were held under a scientific research permit issued by

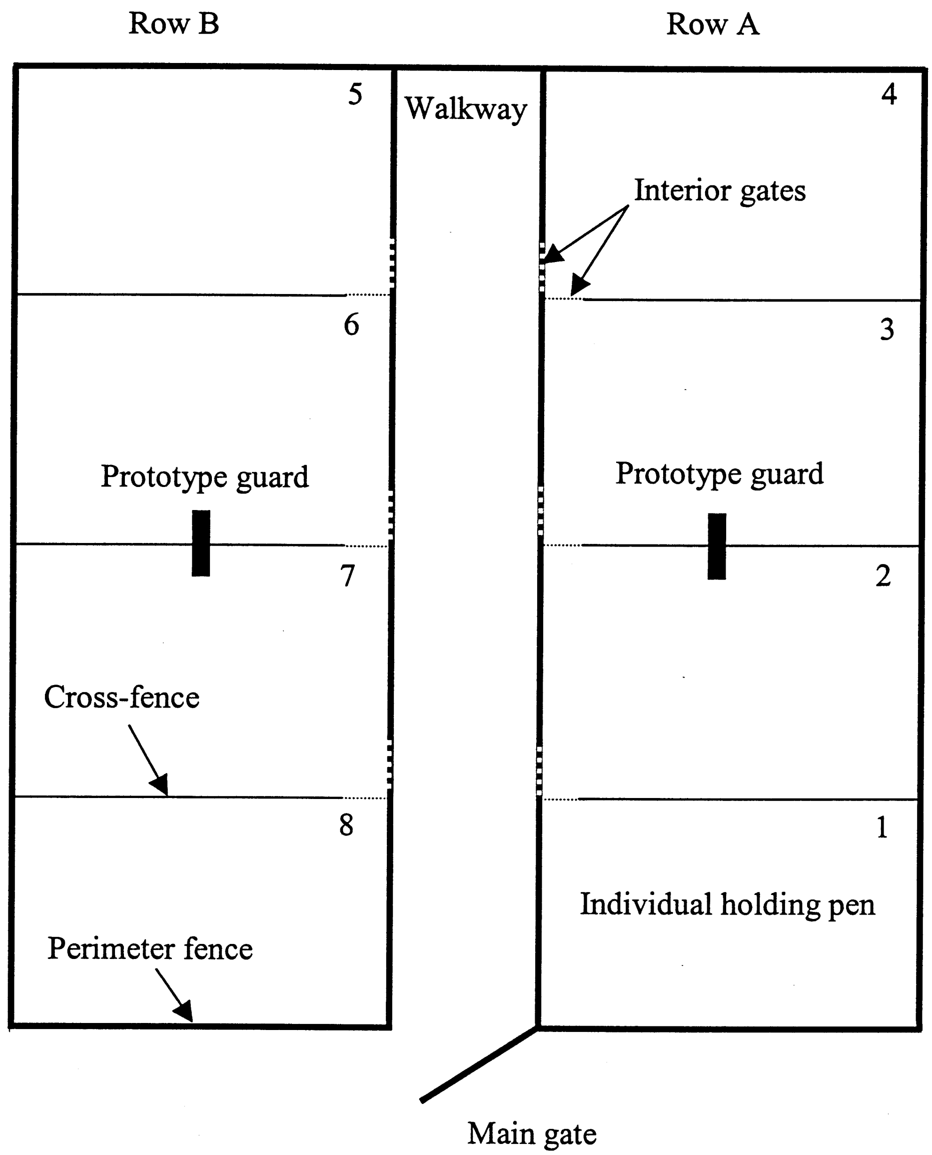

Fig. 3. Aerial diagram of deer pens with location of deer guards installed at Welder Wildlife Foundation Refuge, Sinton, Texas.

Texas Parks and Wildlife to the Welder Wildlife Foundation. My research was conducted under Texas A&M University's approved Animal Use Protocol 9-105. Texas deer were used for the study because of the endangered status of Key deer and because Texas deer were of similar size and physical characteristics.

On 1 September 1998, 4 does and 2 fawns were placed in each row of individual pens for a total of 12 test subjects. All other deer that had been used by Texas Tech University within the facility were released back into the wild. Pelleted food (20% protein) and water (ad libitum) were provided within the adjoining row of 4 pens where the 6 deer were maintained. This design was replicated using the other row of 4 pens.

Deer Guard Prototype Construction

Initially (Sept 1998), 2 deer guards of a single prototype were constructed for simultaneous testing. This design was based on the specifications described by Reed et al. (1974). Guards were 3.7-m long, measured parallel to the flow of traffic, and 1.5-m wide, measured perpendicular to the flow of traffic. Cross-member spacing was set at 10.2 cm. The guard frame was constructed of weather resistant treated 5 x 30-cm lumber, while the cross-members were made of untreated 2.5 x 10.2-cm lumber. Treated 5 x 30-cm frames (Fig. 4) were built in 1.8-m sections to allow ease of handling and movement. Two sections, placed end to end completed the 3.7-m deer guard. Cross-members were attached to the frame by a series of tongue and groove joints that were cut in the interior side of each side frame. This allowed the 2.5 x 10.2-cm cross members to be oriented in a manner so that the 2.5-cm edge was facing upward (Fig. 4).

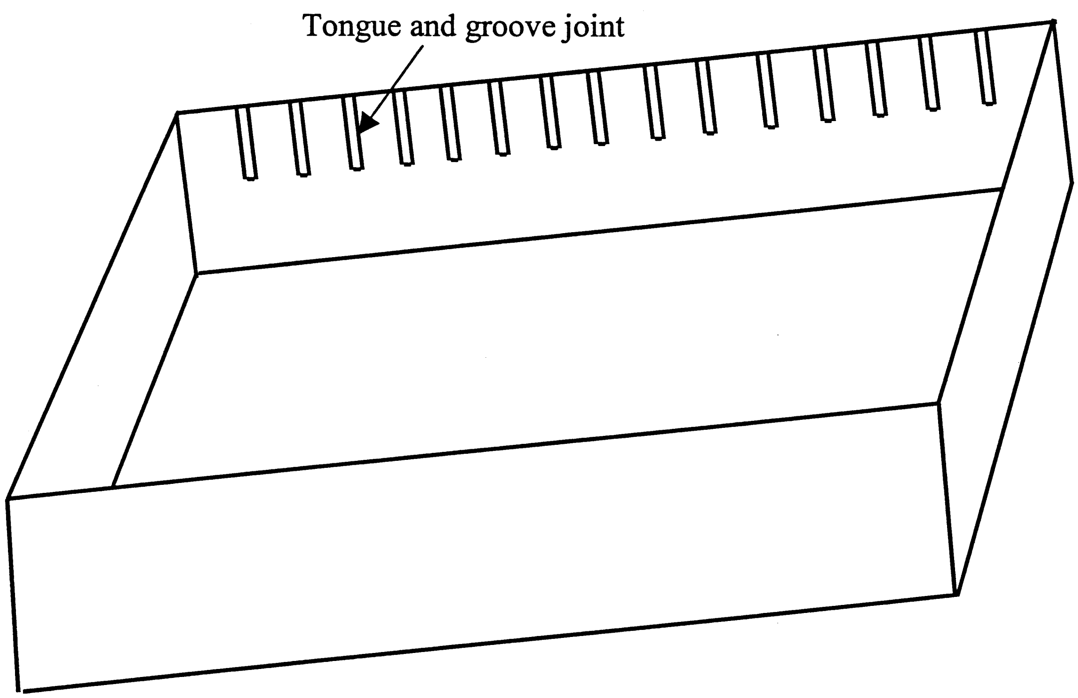

Fig. 4. Aerial diagram of 5 x 30-cm frame (1.8-m length), with tongue and groove attachment illustrated.

Deer Guard Prototype Installation

On 15 October 1998, the 2 (3.7-m) prototypes were installed by cutting out sections of cross fences and placing guards at ground level (Fig. 5). Since the frame of the guard measured 30.5 cm in height, this placed cross-members approximately the same distance above ground level. This type of installation was chosen initially in order to allow deer to reach the ground, thereby preventing injury, if they attempted to cross the guard and fell through the cross-members.

Galvanized, welded cattle panels were attached to the sides of guards perpendicular to cross-fences. Metal t-posts (1.8 m) were driven into the ground as a means to support the panels. The purpose of these panels was to prevent deer from jumping diagonally across the guards, thereby forcing deer to attempt crossing the entire length of the structure. To test the necessity of using panels, 2 different lengths were installed on the prototypes. One guard was outfitted with a cattle panel that ran the length of the guard, while the second incorporated a 2.4-m panel. Fresh soil was placed at each end of the 2 replicated deer guards as well as underneath the guard to allow researchers to identify tracks in order to document crossings or attempted crossings. Two weeks following installation (1 Nov 1998), an additional 1.8-m section was added to the length of both guards. This third section increased the guard length to 5.5 m.

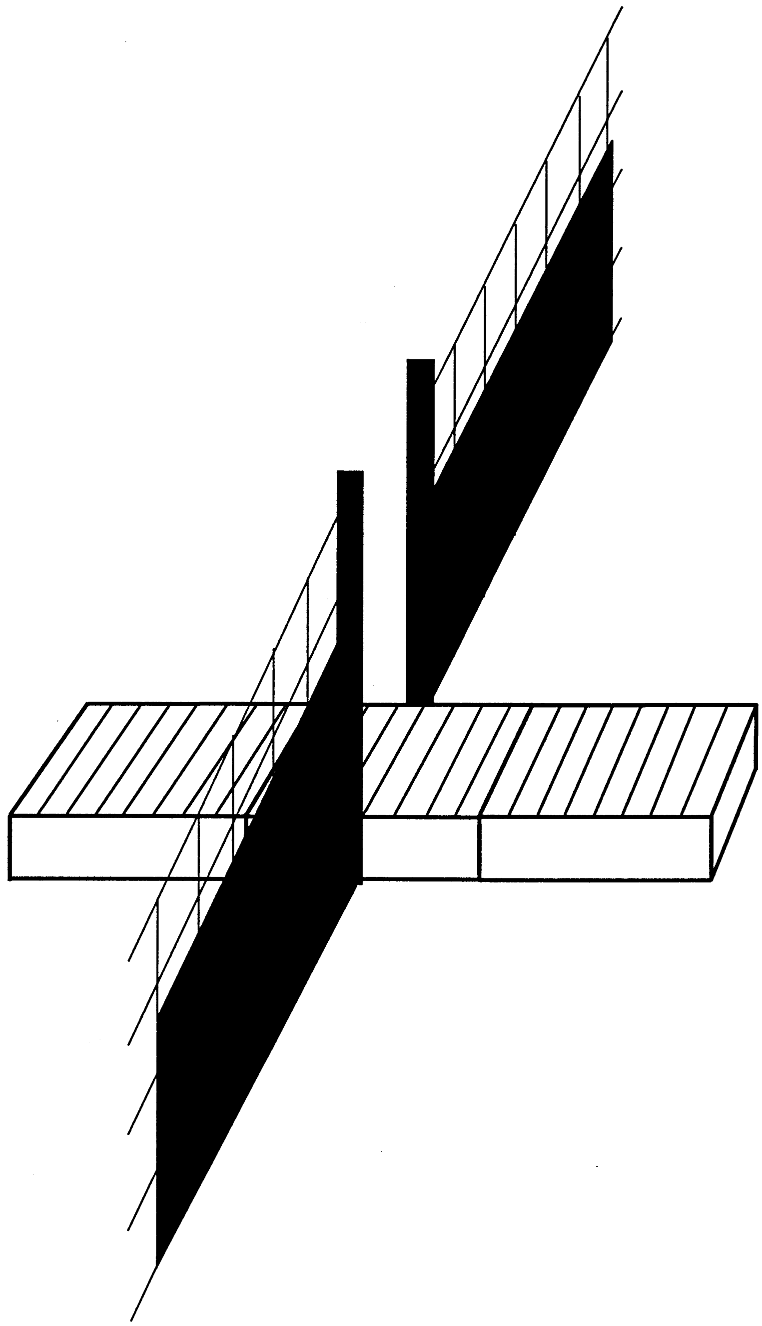

Fig. 5. Aerial diagram of 5.5-m guard (3 sections) installed in cross fence, at ground level.

Guard Modification

During late November 1998, the guards were raised to a level of 0.6 m above the ground by attaching legs cut from 5 x 15-cm treated lumber. Ramps constructed of 1.9-cm treated plywood were placed at each end of the guards to allow deer to easily approach the structure. Ramps were covered with soil in order to disguise them and identify tracks of deer approaching the guards (Fig. 6).

After completion of the first replication of test procedures, guards were then modified to test effects of guards having sloped ends. The purpose of this modification was to evaluate possible effects of a sloped end that may act as a visible deterrent to deer approaching a guard, or attempting to cross a guard. To modify the guards in a sloped-end configuration, legs were removed at opposite ends of the guard allowing the frame to rest at ground level (Fig. 7). This design was intended to offer alternative methods of guard installation in order to compare effectiveness of a raised object that offers obstruction of vision, versus an object installed at ground level that offers little obstruction of vision (Fig. 8). Test procedures were then repeated with the modified guard design and monitored for effectiveness.

Monitoring

In order to monitor deer guard effectiveness, infrared triggered 35 mm TrailMaster cameras (Goodson & Associates, Inc., Lenexa, Kansas) were installed near each guard (1 Nov 1998). The TM 1500 active system was mounted at approximately 61 cm above the ground, in the center of the guard facing the pen containing the deer.

Fig. 6. Raised guard with soil covered ramps attached installed in cross fence at Welder Wildlife Foundation Refuge, November 1998.

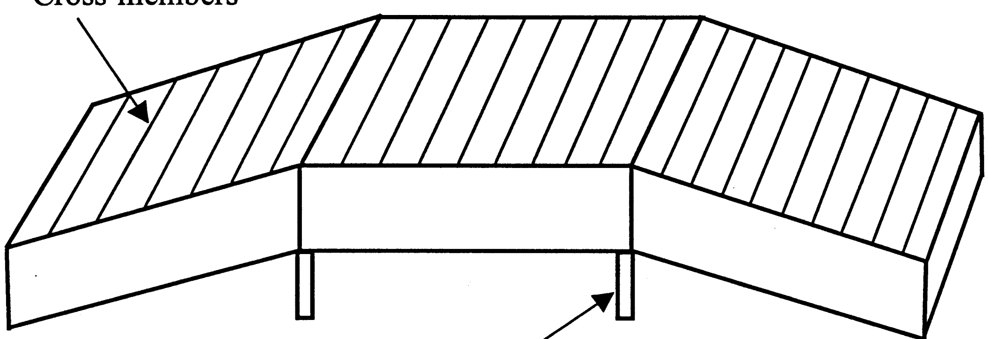

Fig. 7. Aerial diagram of modified guard with sloped sides and legs at ends removed.

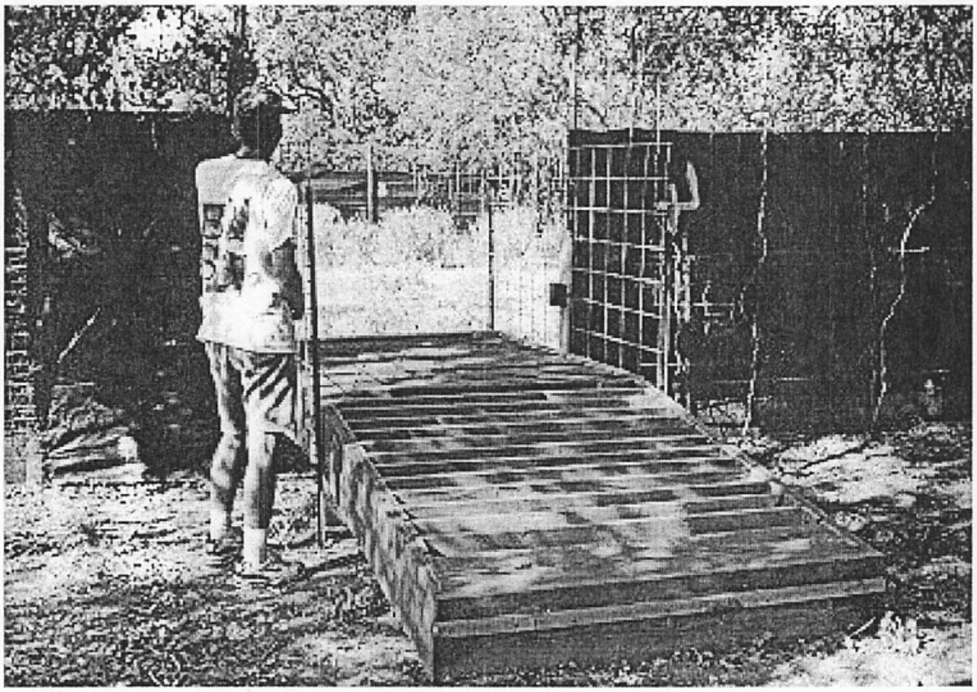

Fig. 8*a*. Sloped guard installed in cross fence at Welder Wildlife Foundation Refuge, Sinton, Texas.

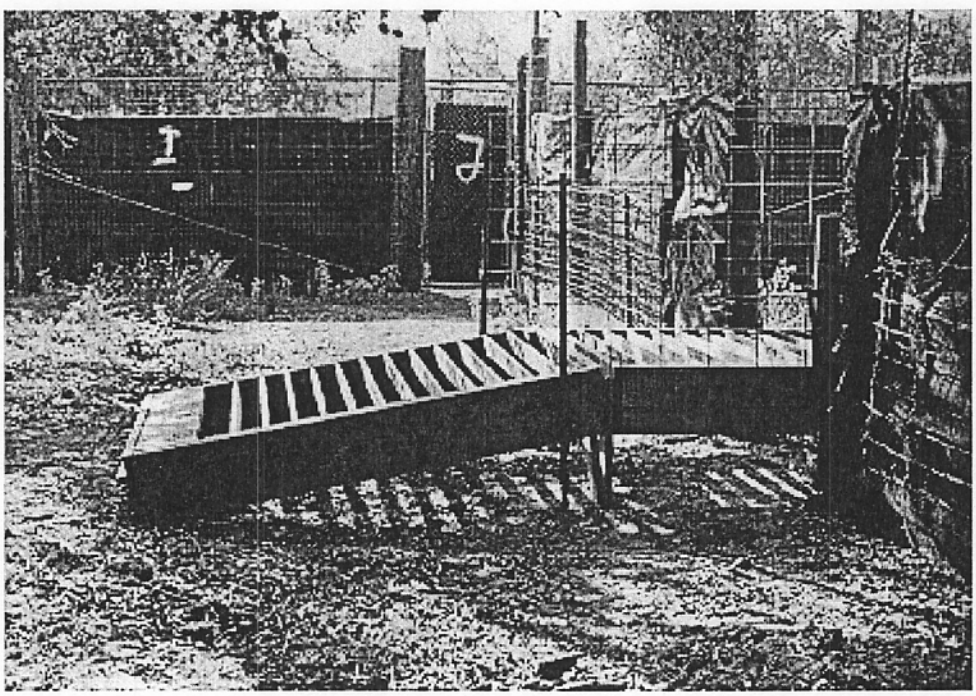

Fig. 8*b*. Side view of sloped guard outfitted with 2.4-m side panel installed in cross fence at Welder Wildlife Foundation Refuge, Sinton, Texas.

Infrared components were attached to fence posts in the cross fence in order to document animals that reached the mid-point of the guard. Remote TM 35-1 cameras were mounted to a 2.4 m pole near the end of each guard in order to get a view of the entire structure.

Additionally, a TrailMaster passive TM 700v video trail monitor was installed in conjunction with an infrared spotlight and Sony 8mm video camera (CCD-TR940) capable of recording in total darkness. The Sony 8mm video camera was housed in a waterproof dry box (MTM Molded Products, Dayton Ohio). The Sportsman's Dry Box measured 35.5 x 19 x 22.9 cm and had a lockable watertight lid. In one end of the box, a window was cut (7.5 x 7.5 cm) and clear glass was installed using silicone rubber to allow video to be taken without exposing the camera to the elements. The waterproof housing, spotlight, and camera were attached to a portable tripod for ease of adjustment and mobility. A deep cycle, 12-volt marine battery was used as a power source for the spotlight and video light controller. The video equipment was installed to collect behavioral data as deer approached and/or crossed the deer guards.

At the beginning of each deer guard test, a blank, 120 min, 8-mm videocassette was placed in the video surveillance camera. When an animal approached a deer guard the video controller was programmed to initialize the camera and collect 1 min of video per event. If the video trail monitor detected no continuous movement, the camera was shut down and no additional video was taken for 10 min. If the sensor detected continuous movement, the system remained active and video was uninterrupted.

This programming scheme allowed video to be collected throughout each 2-week test without running out of tape.

Test Procedures

The first test was designed to determine the length of guard needed to prevent white-tailed deer from jumping the guard. Reed et al. (1974) working with mule deer noted that mule deer would not jump a 3.7-m guard. Between 15-29 October1998, a 3.7-m guard was installed on the ground between pens 2 and 3 (Row A) and replicated between pens 6 and 8 (Row B). Water and food were available within all pens (1-8). Six deer (4 does and 2 fawns) were used with each replicate (Row A and Row B). Guard length was extended to 5.5 m and a second test was conducted from 1-15 November 1998. All other conditions were the same as in the first test.

Once the length of guard needed to prevent white-tailed deer from jumping was determined, 2 guard prototypes (raised and sloped ends) were tested using 4 different test protocols. The 4 test protocols designed to evaluate the effectiveness of deer guards were: (1) a no-incentive test; (2) additional food and water test; (3) a fawn/doe separation test; and, (4) a rutting buck separated from an estrous doe test (Table 1).

Table 1. Dates, duration, and test procedures used to test 2 deer guard prototypes, September 1998-December 1999.

Procedure	Non-raised (n)		Raised (n)		Date	Duration
	3.7 m	5.5 m	no-slope	sloped		(Days)
No-Incentive	2	2	2	2	Nov 98	14
	2	2	2	2	Sep 99	14
Food/Water	2	2	2	2	Dec 98	14
	2	2	2	2	Oct 99	14
Doe/Fawn	2	2	2	2	Dec 98	2 hrs
	2	2	2	2	Oct 99	2 hrs
Buck/Doe	2	2	2	2	Oct-Dec 99	14

No Incentive Test.--For this test 6 deer (4 does and 2 fawns) were placed in holding pens 3-4 and replicated with 6 deer (4 does and 2 fawns) placed in pens 5-6 (Fig. 3). Opened doors allowed free movement of deer among pens 3, 4 and pens 5, 6, respectively, while guards were the only obstructions to movement between the additional holding pens. No food or water was placed in pens 1, 2, 7, and 8, therefore there was nothing to encourage deer to cross the deer guards. This test was developed to duplicate a naturally occurring scenario where a deer may try to enter a fenced roadway. Activities were monitored for 14 days (15 Nov-29 Nov 1998, 15 Sep-29 Sep 1999).

Food/Water Manipulation Test.--For this test, deer were placed in holding pens as per the no incentive test. Animals were fed and watered at a normal rate in pens 3 and 6, while additional water and food were placed in pens 2 and 7 to encourage deer to cross the guards. A more attractive feed (sweet feed) was used in pens 2 and 7. Guards were monitored and tests were run for 14 days (1-14 Dec 1998, 1-14 Oct 1999).

Doe/Fawn Separation Test.--For this test, 2 adult does were separated from their respective fawns and the rest of the deer herd. Deer not used in this test were placed in pens 4 and 5. Fawns isolated from their does were placed in pens 2 and 7, respectively. The mothers of the 2 fawns were placed in pens 3 and 6, respectively. Deer guards were the only obstruction to the adult does reaching their fawns. Due to the stress caused by this test to the animals, a maximum separation time of 2 hours was implemented. During this test, animals were monitored on site by researchers, while deer behavior and guard effectiveness was recorded. All deer had food and water available as in previous tests. This test was conducted on 15 December 1998 and replicated on 15 October 1999.

Buck/Doe Separation Test.--For this test, 2 bucks were placed in holding pens 2 and 7 adjacent to captive female deer in pens 3-4 and 5-6, respectively. When the breeding season started (tests were delayed until 15 Oct 1999 due to timing of breeding season), and adult does began their estrous cycles, gates were closed in pens 3 and 6 to isolate bucks from the rest of the captive herd. The receptive does were placed in pens 2 and 7, respectively. Deer guards were the only obstruction to rutting bucks reaching receptive does. Tests were run from 15 October-31 Dec 1999, and guards monitored for 2 weeks.

RESULTS AND DISCUSSION

Prototype Test Results

Deer Guard Prototype (3.7 m).--The original prototype installed at ground level was unsuccessful at preventing deer crossings. Deer were able to jump the 3.7-m guard in the early stages of the no-incentive test. This was determined by observation of tracks as deer jumped the prototype, as well as presence of deer in the original vacant holding pens. Since deer were able to jump the original 3.7-m prototype, these deer guards which were similar to those designed by Reed (1974) were ineffective at preventing the smaller, more agile white-tailed deer from crossing. Because of the jumping problem, no further tests were conducted with this prototype. The decision was then made to extend the guard to 5.5 m.

Deer Guard Prototype (5.5 m).--Guards extended to 5.5 m prevented deer from jumping the guards. Although extending the original prototype to 5.5 m prevented deer from jumping, it did not prevent them from crossing. With guards installed at ground level, deer were able to step between cross-members and walk the length of the structure. This behavior was captured by the infrared triggered 35-mm camera system. Early in the study, guards were installed at ground level to prevent injury to deer that were unfamiliar with the structures. Once deer became comfortable approaching and inspecting the structures they soon learned that by stepping between cross-members they could touch ground and walk across the guards (Fig. 9). Because of the crossing problem, no further tests were conducted using this prototype. The decision was then made to raise the guards so that if a deer attempted to step through cross-members the deer would not be able to touch ground.

Deer Guard Prototype (5.5-m raised).--No animals crossed the 5.5-m guards once they were raised to 0.6 m during the no-incentive, food/water manipulation, or the doe/fawn separation tests during 1998 and 1999. The buck/doe separation test for 1998 was postponed because the adult male, that was to be used in this test, jumped out of the deer holding facility prior to the start of this test. No deer crossed this prototype during the buck/doe separation test conducted in December 1999.

Since no deer crossed the raised guard design by jumping or stepping through cross-members, this design proved effective in preventing deer from crossing the guards. The raised guard prevented these occurrences probably because of the visual obstruction value (i.e. deer had difficulty seeing over it), and the fact that deer could no longer touch ground when they stepped through cross-members. Although no deer crossed the 5.5-m raised guard, an alternative design sloped end design also was tested.

Deer Guard Prototype (5.5 m sloped).--No deer crossed the sloped 5.5-m guards during the 2 week no-incentive tests in 1998 and 1999. Two deer were photographed jumping diagonally across 1 of the sloped guards during the food/water incentive test. This particular guard was outfitted with only 2.4-m cattle side panels during the 1999 food/water incentive test. No deer crossed the other guard of this prototype that was outfitted with full-length side panels. There were no crossings during the doe/fawn separation tests in either year. No deer were documented crossing the guard during the buck/doe separation test in 1999.

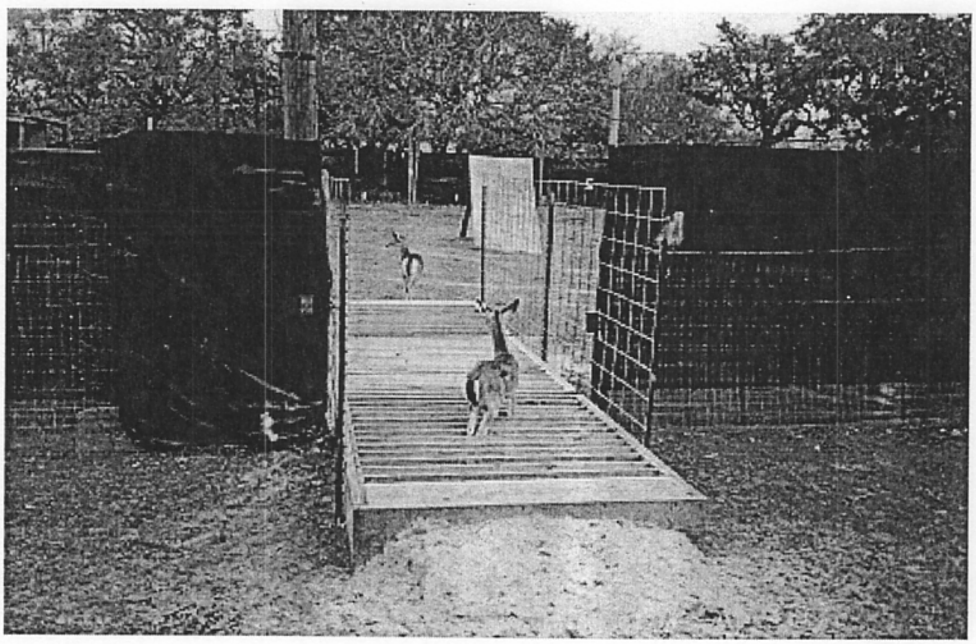

Fig. 9. Deer stepping through cross-members of 5.5-m guard installed at ground level in cross fence at Welder Wildlife Foundation Refuge during no-incentive test.

On 2 independent occasions a yearling buck was able to get into the adjacent pen with a receptive doe, although no photographs or video images were recorded. This buck was later observed to jump the interior 2.8-m high fence separating him from the doe. The other buck in the replicate test was never observed to cross into pens holding receptive does.

Raised guards were modified to a sloped-end configuration for comparison by removing ramps and legs at each end. I wanted to see if positioning cross-members at a slight angle would have any bearing on the guard's efficacy. During the study, an occasion was documented of a deer jumping the 5.5-m sloped guard when a person entering the pens spooked it. The deer approached the guard at high speed and jumped into the structure, becoming temporarily entangled in cross-members, until it was ultimately able to roll off of the structure. This guard was outfitted with the 2.4-m side panels. Aside from the 2 deer that were able to diagonally jump the guard outfitted with the 2.4-m side panels, no other crossings were documented with the 5.5-m sloped guards.

Monitoring

Infrared triggered 35 mm.--From 1 September 1998-15 December 1999 a total of 188 events were recorded by the infrared triggered 35-mm camera system. Of the 188 total events captured by infrared cameras, deer triggered 43 (Table 2). These events were caused by deer physically breaking the infrared beam, but did not necessarily represent an animal that broke the beam while crossing or attempting to cross a guard. Events were recorded at each guard design, excluding the original 3.7-m prototype, which was not monitored by cameras. Events were analyzed and categorized based on type of animal causing the event. If reason for triggering could not be determined the event was categorized as unknown (Table 2).

Table 2. Events recorded by TrailMaster 35-mm surveillance system including guard design and source of triggering.

Design	Human	Bird	Squirrel	Raccoon	Deer	Unknown	Malfunction
Ground	7	3	0	1	3	11	0
Raised	5	1	1	7	0	17	23
Sloped	12	6	0	0	40	29	22

Infrared Triggered Video.--A total of 480 min of data were collected by video surveillance throughout the study. During the 2-week no-incentive test there were several occurrences of deer approaching the guard, but no attempts at crossing. Video data collected during the food/water manipulation test showed similar deer behavior, deer casually approached guards but made no attempt at crossing. During the 2-hour doe/fawn separation test, each test subject was recorded as they aggressively approached the guards (i.e. running up to the guards) but no attempts at crossing were made. During the buck/doe separation test, deer were recorded approaching the guards but no attempts at crossing were recorded.

During the study (1year) a total of 5 deer was recorded crossing a guard. Three of the 5 deer were able to cross the 5.5-m guard that was installed at ground level. Since the 5 x 30-cm frame held cross-members at approximately 30 cm above ground, deer were able to step through them and walk the length of the guard. This illustrated the importance of having guards installed in such a way that a deer's legs could not reach solid ground below the structure, allowing them to walk across.

Two deer crossed the 5.5-m sloped guard that was outfitted with 2.4-m side panels. They were photographed jumping diagonally (~3 m), instead of having to clear the entire length of the guard (5.5 m). Since no deer crossed the sloped guard that was outfitted with full length side panels, this illustrated the importance of having side panels that extended the total length of a guard versus side panels that only covered a portion of the guard's length.

Based on the results of this study, I found the 5.5-m guards (raised/sloped) to be an effective device for preventing deer from crossing. Used in conjunction with high fences and wildlife crossings, deer guards could be a valuable device for reducing highway mortality of Key deer on Big Pine Key, Florida. Based on findings from my research I conclude that installation of guards at access points along US-1, deer/vehicle collisions could be reduced, thus decreasing highway mortality of Key deer. Although the deer guard design is not perfect and may not prevent all deer from crossing, data indicates that it will be effective under normal circumstances and will reduce Key deer mortality.

In addition to the benefits from its intended design, deer guards can be valuable with slight modifications at reducing highway mortality of other species of ungulates. Reed's (1974) deer guard design was ineffective at preventing mule deer from walking cross-members, while our similar design was effective at preventing smaller hoofed white-tailed deer from crossing. Over-population of white-tailed deer herds across the United States has been an emerging issue in recent years. Fencing in conjunction with my deer guard design could be useful in keeping deer out of residential areas, thus reducing deer/human conflict. Game-resistant fencing has become a popular method of keeping wildlife in or out of private property, ranches, and hunting preserves. The deer guard designed and tested during this study could be a valuable asset to an operation that has high traffic areas or does not want to install traffic impeding gates. With a slight modification in cross-member spacing, this design should work for different sized animals (i.e. larger spaces for larger hooves). In addition, changes in guard dimensions such as length, width, slope angle, and/or height of guard could be incorporated in order to match physical and behavioral characteristics of many animals.

CONCLUSIONS

After 1 year of testing and several modifications to the original deer guard prototype, I recommend to FDOT the following design specifications and guidelines for construction and installation of deer guards for Key deer. These recommendations are somewhat more stringent then the designs I tested, however, because of the endangered status of Key deer, I believe they are necessary.

Guard Specifications

1. Length measuring at least 7.3 m (measured perpendicular to fence).
2. Guard positioned so that entire length is on outside of fence placed along road.
3. Width to be determined by width of road and by FDOT engineers.
4. Center portion of guard raised 0.6 m above ground level (guards placed above grade level).
5. Sloped end configuration (proportion of sloped ends should be minimal and determined by FDOT engineers so as not to affect vehicle access).
6. Cross-members spaced at 10.2 cm.
7. Top surface width of cross-members 1.9 cm or less.
8. Side panels/fencing extending entire length of guard (~7.3 m).
9. Materials for guard construction to be determined by FDOT engineers.

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