Florida Key deer Odocoileus virginianus clavium underpass use and movements along a highway corridor

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SHORT COMMUNICATION

Short communication articles are short scientific entities often dealing with methodological problems or with byproducts of larger research projects. The style is the same as in original articles

Florida Key deer *Odocoileus virginianus clavium* underpass use and movements along a highway corridor

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In order to address endangered Florida Key deer *Odocoileus virginianus clavium* vehicle collisions along a 5.6-km segment of United States Highway 1 (US 1), the Florida Department of Transportation (FDOT) constructed a 2.6-km long system of fencing, deer guards and two underpasses to exclude deer from roadway. The US 1 project was completed in 2002 for the purpose of minimizing Key deer mortality and maintaining deer permeability through the Big Pine Key (BPK) corridor, Florida, USA. We evaluated the potential impact of these modifications to Key deer movements by comparing 1) annual ranges and movements of Key deer pre- (January 1998 - December 2000) and post-construction (February 2003 - January 2004), 2) deer-vehicle collisions on US 1 pre- and post-construction, and 3) underpass use post-construction. Mean female and male annual ranges and core areas did not change ($P > 0.05$) between pre- and post-construction. Deer movements within the US 1 project area were comparable pre- (six of 23 radio-collared deer crossed the corridor) and post-project (four of 16). Key deer-vehicle collisions were reduced by 94% inside the fenced segment. Experimental deer guards and fencing minimized Key deer entry into the project area to eight deer during the first-year resulting in two deer mortalities (one deer-vehicle collision, one severe removal injury). Infrared-triggered camera data indicate that underpass movements increased over time, suggesting that an acclimation period is necessary for highway underpasses to be successful. Collectively, post-project data indicate that highway alterations have not restricted Key deer permeability while minimizing Key deer mortality; however, our study results suggest changes in deer movement patterns within the corridor. We recommend continued monitoring to verify accurate trends in deer use of wildlife underpasses and permeability across fenced areas.

Key words: camera monitoring, deer guard, fencing, Florida, Key deer, Odocoileus virginianus clavium, radiotelemetry, road mortality, wildlife crossings

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Florida Key deer *Odocoileus virginianus clavium* are the smallest subspecies of white-tailed deer in the United States occupying 20-25 islands in the Lower Florida Keys. Approximately 65% of the overall population is found on Big Pine Key (BPK; Lopez et al. 2004a), which serves as a source population for surrounding islands (Hanski & Gilpin 1997, Harveson et al. 2004). Since the 1960s, deer-vehicle collisions have been the single largest Key deer mortality factor accounting for > 50% of annual losses (Lopez et al. 2003b). United States Fish and Wildlife Service (USFWS) recorded 69 Key deer-vehicle collisions, for example, on BPK in 2000 (USFWS, unpubl. data). Because of this, USFWS and Florida Department of Transportation (FDOT) have attempted to address deer-vehicle collisions on United States Highway 1 (US 1) which bisects BPK (Fig. 1). This highway is the only transportation corridor linking the entire lower Florida Keys to mainland Florida.

In 1994, the Key Deer-Motorist Conflict Study was initiated by FDOT to evaluate alternatives for reducing deer-vehicle collisions along the US 1 highway (Lopez et al. 2003a). During the planning process, deer movements were of concern because of potential negative impacts from the proposed US 1 improvements (i.e. fencing, underpasses; hereafter the US 1 project area) within the narrow (< 150 m) natural corridor (hereafter the BPK corridor). The BPK corridor is the sole land connection between north and south BPK (south BPK also joins Newfound Harbor Keys; see Fig. 1). A recent study of Key deer movements reported that deer on north BPK served as a 'source' population for deer populations in south BPK (Harveson et al. 2004), emphasizing the importance of understanding deer movements within the proposed US 1 project area. Final study recommendations included construction of barriers (fences) with four deer guards (modified cattle guards used to prevent deer access; Peterson et al. 2003) and two wildlife underpasses along an undeveloped segment of US 1 on BPK (Lopez et al. 2003b). In 2002, construction of the 2.6-km fenced segment (fence height 2.4 m) with two box underpasses (14 × 8 × 3 m) and four experimental deer guards (Peterson et al. 2003) for the US 1 project was completed. Experimental deer guards are similar to traditional cattle guards but differ in width (approximately two times the width of standard cattle guards) and grate material (bridge grate material used instead of a series of steel tubing, see Peterson et al. 2003 for details).

Our study objective was to assess the potential impacts of US 1 highway improvements on BPK to Key deer movements. Specifically, our study objectives were to 1) compare southern BPK radio-collared Key deer annual ranges (95% and 50% probability areas) pre- and post-project implementation, 2) compare radio-collared deer corridor movements pre- and post-project, 3) compare deer-vehicle collisions on US 1 pre- and post-project, 4) determine the ability of deer to access the fenced

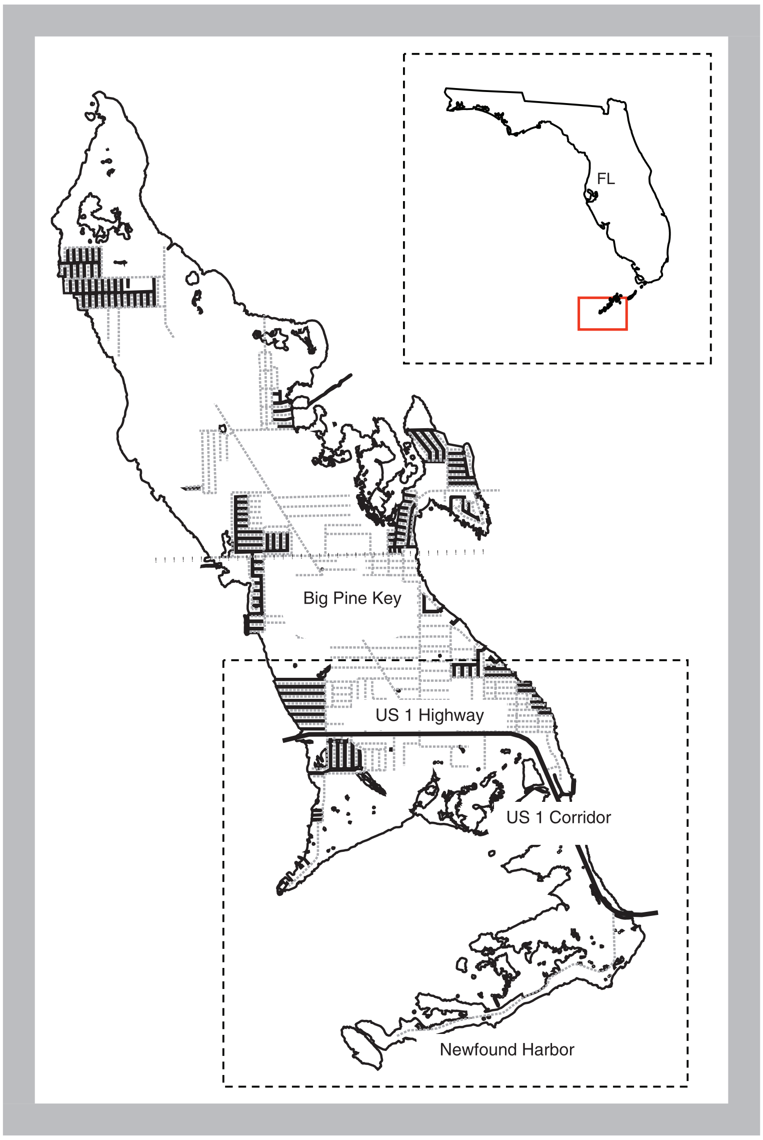

Figure 1. The project area (dashed line) including United States Highway 1 (US 1, black line), US 1 corridor (gray shaded area, highway fenced within this area only), south Big Pine Key (BPK, south of US 1 corridor), north BPK (north of US 1 corridor), and Newfound Harbor Keys, Monroe County, Florida, USA.

project area, and 5) assess Key deer underpass and corridor use post-project implementation using infrared-triggered cameras.

Study area

US 1 is a 2-lane highway that links the Keys to the mainland with an estimated annual average daily traffic volume of approximately 18,000 vehicles/day (FDOT data, Monroe County, 2004). US 1 bisects the southern half of BPK with maximum posted speed limits of 72 km/hour during the day and 56 km/hour at night (see Fig. 1). Vegetation near sea level and in tidal areas on BPK is comprised of black mangrove *Avicennia germinans*, red mangrove *Rhizophora mangle*, white mangrove *Laguncularia racemosa*, and buttonwood *Conocarpus erectus* forests. With increasing elevation, maritime zones transition into hardwood (e.g. gumbo limbo *Bursera simaruba* and Jamaican dogwood *Piscidia piscipula*) and pineland (e.g. slash pine *Pinus elliottii* and saw palmetto *Serenoa repens*) upland forests with vegetation intolerant of salt water (Lopez et al. 2004b).

Material and methods

Trapping and radiotelemetry

Florida Key deer were radio-marked as part of two separate research projects conducted during January 1998 - December 2000 (hereafter 'pre-project') and February 2003 - January 2004 (this study, hereafter 'post-project') on BPK. We captured Key deer using portable drive nets (Silvy et al. 1975), drop nets (Lopez et al. 1998), and hand capture. We used physical restraint to hold animals without drugs (average holding time of 10-15 minutes), and deer were marked in various ways depending on sex and age. We used a battery-powered, mortality-sensitive radio-transmitter (100-110 g for plastic neck collars, 10-20 g for antler transmitters and elastic collars, Advanced Telemetry Systems, Isanti, Minnesota, USA) attached to plastic neck collars (8-cm wide, females of all age classes), leather and nylon antler collars (0.25-cm wide, yearling and adult males only), or elastic expandable neck collars (3-cm wide, male fawns/yearlings). Each captured animal received an ear tattoo as a permanent marker. For each radio-collared deer, we recorded sex, age (fawn, yearling, adult;

Severinghaus 1949), capture location and body mass. We relocated radio-marked deer via homing (White & Garrott 1990) 6-7 times/week at random intervals (24-hour period was divided into six equal 4-hour segments; one 4-hour segment was randomly selected, and during that time all deer were located). Telemetry locations were entered into a Geographical Information System (GIS) using ArcView (Version 3.2).

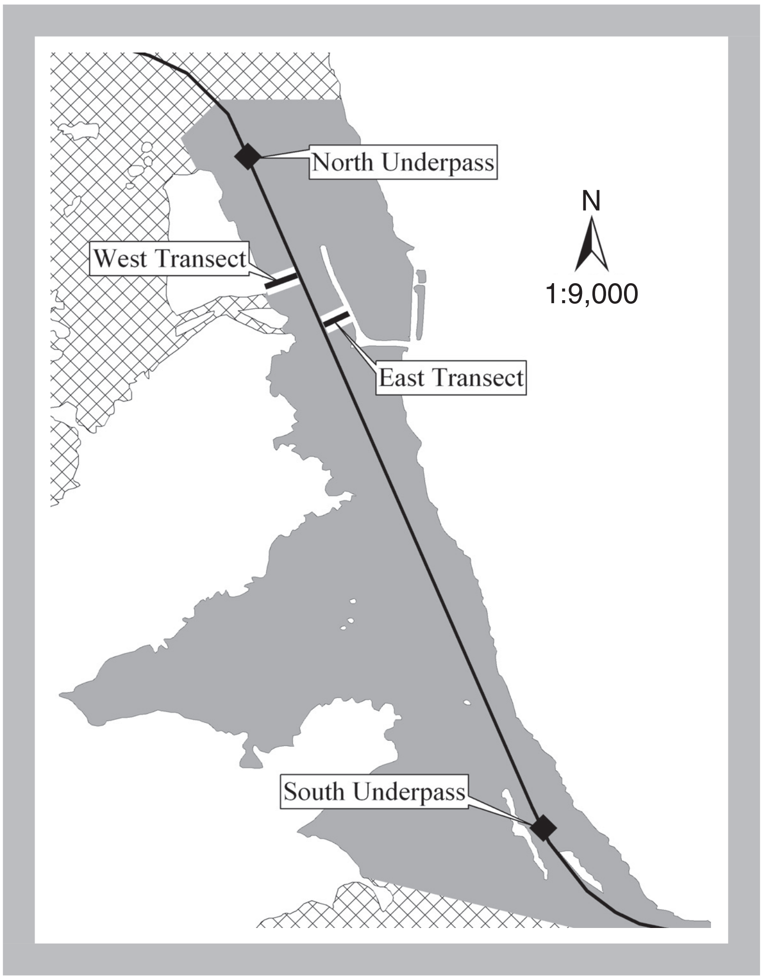

Figure 2. The US 1 corridor (shaded area; crosshatched area = other land mass) and denoted infrared-triggered camera transects used to monitor Key deer movements on Big Pine Key, Florida, USA, in 2003. The highway segment within the project area (gray shaded area) was fenced whereas highway segment in adjacent areas (crosshatched areas) were not fenced. Note that camera transects terminate into water bodies (i.e. canal on the east transect, bay on the west transect).

Deer-vehicle collisions

Since 1966, USFWS biologists have recorded Key deer mortality on all roads on BPK via direct sightings, citizen and law enforcement reports, and observation of turkey vultures *Cathartes aura* (Lopez et al. 2003a). Age, sex and body mass were recorded for each dead animal, and all road-related deer mortality locations were entered into a GIS using ArcView (Version 3.2) and Microsoft Access (Version 2000). In addition, the number, age, sex and point of entry of all known deer inside the fenced segment based on direct sightings and local law enforcement reports were estimated and recorded. Removal of deer from the fenced segment was conducted when necessary using maintenance side swing gates (N = 16) installed during initial con struction.

Camera transects

TrailMaster 1500 Active Infrared Trail Monitors (TrailMaster, Goodson and Associates, Inc., Lenexa, Kansas, USA) consisting of a transmitter, receiver and a 35-mm camera (Jacobson et al. 1997) were placed in the center of each underpass (north underpass and south underpass) and perpendicular to the US 1 roadway across the full width of the corridor (hereafter camera transect; west transect = seven cameras and east transect = one camera) to monitor deer underpass and corridor movement, respectively (Fig. 2). The latter was an attempt to monitor Key deer movements through the natural corridor in addition to underpass use. The selection of camera transects were located based on the shortest distance from highway fence to shoreline, thus, the number of west and east transect cameras differed due to transect lengths (west transect = 90 m, east transect = 14 m). Camera stations collected data for one year (February 2003 - January 2004) following project completion. Cameras were set to take pictures throughout the day (00:01-24:00) with a camera delay of two minutes (Jacobson et al. 1997) to avoid double counting. A camera delay of two minutes was assumed to be of adequate length because of the lack of incentive for Key deer to stay within the camera's line of sight. For example, the camera areas were comprised of bare limestone gravel with no vegetation. Thus, deer captured in photos were typically passing through. Furthermore, our intent in gathering information about deer movements within underpasses and along camera transects was to obtain a relative measure of deer use. Though double counting was possible, our use of camera data as a relative index to deer use allowed comparison between underpasses and camera transects. The number, sex, age and location of deer were recorded and entered into an Access database.

Statistics

Ranges and core areas

We compared Key deer annual ranges pre- and post-project using telemetry data. We restricted our analysis of movements and ranges to radio-collared deer with > 90% of their locations within the project area to evaluate specific effects of highway improvements. We calculated Key deer annual ranges (95% probability area) and core areas (50% probability area) using a fixed-kernel home-range estimator (Worton 1989, Seaman et al. 1998, Seaman et al. 1999) with the animal movement extension in ArcView (Version 2.2; Hooge & Eichenlaub 1999). Calculation of the smoothing parameter (kernel width) as described by Silverman (1986) was used in generating kernel range estimates. Annual ranges (ha) and core areas (ha) of yearling and adult deer were calculated by sex for the pre- and post-project periods. We used the non-parametric Mann-Whitney U-test ($\alpha = 0.05$) to compare differences in Key deer ranges and core areas by period and sex.

Corridor use and movement patterns

We compared the frequency of radio-collared Key deer that crossed the project area pre- and post-project. To compare the number of radio-collared deer that crossed the project area, we assigned individual telemetry locations to a given category: 1) within US 1 project area, 2) north of US 1 project area, and 3) south of US 1 project area. Key deer with locations in all three areas were classified as having crossed the entire BPK corridor. Key deer with locations within the project area and on only one side of the project area (north or south, but not both) were classified as non-crossers. We also evaluated radio-collared Key deer movements inside the BPK corridor with respect to their position along the corridor (i.e. west or east side of US 1; see Fig. 1). The number of collared deer that used both sides of US 1 (west and east) versus only one side (either west or east) was compared between the pre- and post-project implementation periods using a χ^2-test to evaluate movement patterns within the BPK corridor itself (SPSS 2001).

Deer-vehicle collisions and crossing events

Using the road mortality data, we compared annual pre-fence (1996-2000) US 1 deer-vehicle collisions to post-fence (2003-2004) annual US 1 deer-vehicle collisions. Key deer mortality data from 2001 and 2002 were excluded to avoid biases during the construction phase of the project.

Underpass use

We compared Key deer underpass and BPK corridor use post-project implementation using infrared-triggered camera data. Specifically, we compared average monthly camera exposures between underpasses and camera transects by semi-annual period (1-6 months and 7-12 months following the completion of the US 1 corridor project) using Tukey's HSD procedure (t-test adjusted for multiple comparisons; SPSS 2001).

Results

Ranges and core areas

We captured and radio-collared 76 Key deer during both study periods (pre-project = 16 females and 28 males; post-project = 24 females and eight males) without any capture-related mortality. For annual range and core area analysis, we used 62 deer (pre-project = 16 females (221 mean locations ±160 SD) and 19 males (108 mean locations ± 73 SD); post-project = 23 females (143 mean locations ±63 SD) and four males (73 mean locations ±45)). Mean pre-project female (45 ha ± 48 SD) and male annual ranges (148 ha ± 176 SD) were similar ($P = 0.38$ for females and $P = 0.57$ for males) to post-project ranges (female 73 ha ± 94 SD and male 84 ha ± 80 SD). Furthermore, mean pre-project female (6 ha ± 8 SD) and male annual core areas (22 ha ± 31 SD) were similar ($P = 0.29$ for females, $P = 0.69$ for males) to post-project implementation core ranges (female 12 ha ± 18 SD and male 13 ha ± 12 SD).

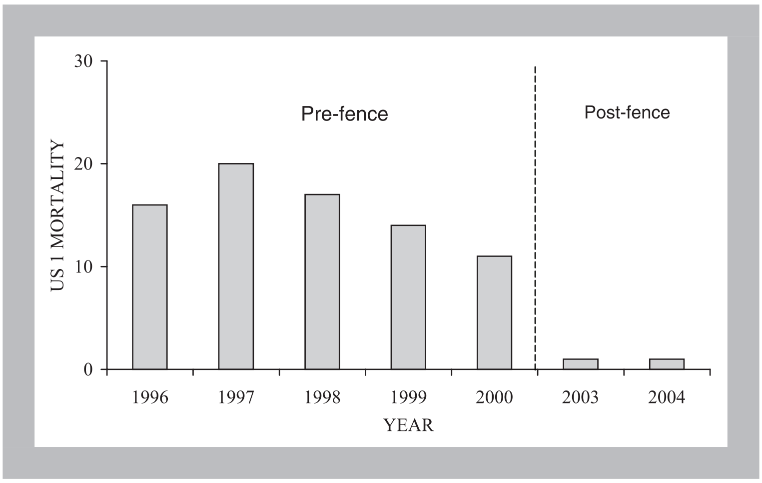

Figure 3. Annual Key deer-vehicle collisions on US 1 Highway (fenced segment), Big Pine Key, Florida, 2003.

Corridor use and movement patterns

Pre- and post-project telemetry data indicate a comparable number of radio-collared deer entered the US 1 corridor (pre-project = 55% (24/44) and post-project = 53% (17/32)). Of the deer entering the project area (N = 41), the number that crossed the entire corridor at least once was comparable pre- (approximately 26%, 6/23) and post-project (25%, 4/16). The distribution of radio-locations within the project area (use of habitat on both sides of US 1 by individual deer; see Fig. 1), however, was found to be different ($P < 0.01$) pre- and post-project implementation. All (9/9) of the pre-project deer had locations on both sides of US 1 (west and east) while only 45% (5/11) of post-project deer had locations on both sides of US 1.

Deer-vehicle collisions and crossing events

Deer-vehicle collisions decreased approximately 94% (Fig. 3) following the completion of the US 1 project for the fenced section. Eight deer entries into the fenced segment were recorded (six deer-guard crossings, two open side-gate entries) following the completion of the project. A majority of deer guard crossings occurred at night (N = 4; two adult males and two adult females) rather than during the day (N = 2; two adult males). The eight deer incidents resulted in two Key deer mortalities within the fenced segment of the project (one following a vehicle collision; the other had to be euthanized after it was severely injured during a removal attempt). Of the six surviving deer, four deer crossed back over a deer guard to exit the fence and two deer exited through side gates.

Underpass use

Of the 2,522 photographic exposures recorded, only 25 contained >1 deer. During the first six months, average camera exposures for transects were greater ($P < 0.01$) than for underpass exposures. Average camera exposures for months 7-12 after project completion, however, were similar ($P = 0.38$) between the BPK corridor camera transects and underpass cameras (Figs. 4 and 5). In comparing corridor and underpass by sex, male use of the project area was greater ($P < 0.01$) with approximately two times more use than females. We found that camera transect exposures did not differ (east transect, $P = 0.40$; west transect, $P = 0.06$; combined transects, $P = 0.08$) during the first six months compared to 7-17 months post-project completion. However, underpass camera exposures increased (north underpass: $P < 0.01$; south underpass:

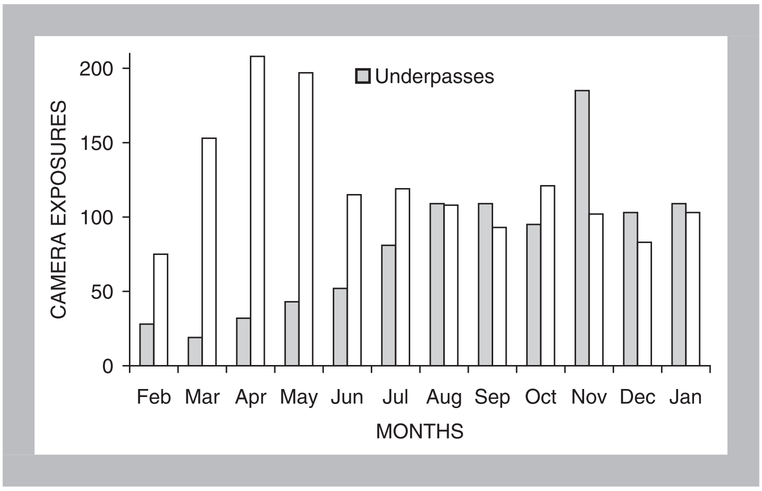

Figure 4. Monthly Florida Key deer camera exposures for deer movements along the corridor (west and east camera transects) and underpass (north and south underpasses) following the completion of the US 1 corridor project, Big Pine Key, Florida, 2003.

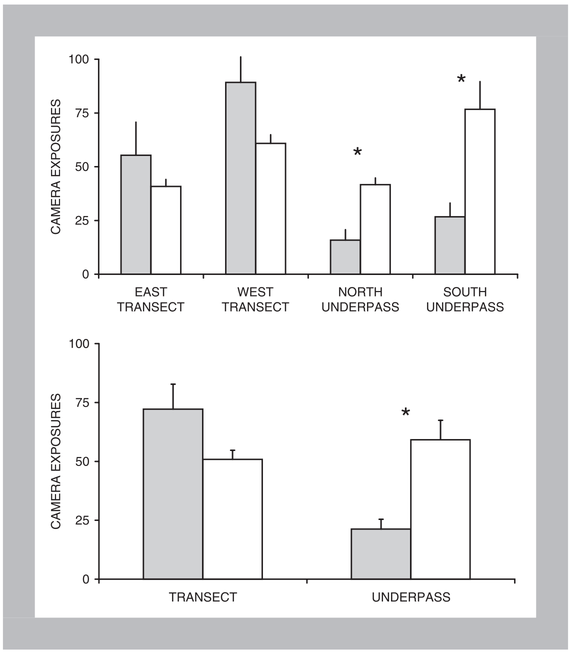

Figure 5. Average monthly camera exposures (mean, 1 SD) of Key deer by area and period (■: 1-6 months, □: 7-12 months) on Big Pine Key, Florida, 2003. Asterisks indicate a difference at $\alpha = 0.05$.

$P = 0.03$; combined underpass: $P < 0.01$) following a 6-month acclimation period (see Fig. 4).

Discussion

Ranges and corridor use

We found no difference in female and male annual ranges and core areas between the pre- and post-project implementation periods. We attribute a lack of difference in our range and core area comparison to Key deer adapting to the fencing of US 1 (i.e. reshaping of ranges and core areas) and the features of the US 1 project (i.e. underpass locations) that facilitated that adaptation. Pre- and post-project ranges results, however, also could be attributed to low sample sizes, which may partially explain the lack of power in our analyses. Because of these factors, determining the impacts of the project on deer ranges and core areas should be interpreted with caution. Telemetry data indicates a comparable number of radio-collared deer entered the US 1 corridor, suggesting the US 1 project can maintain deer movements. However, we also found deer movement patterns within the BPK corridor did differ between pre- and post-project evaluation periods. The changes in the distribution of radio-collared deer locations pre- and post-project are important because it suggests altered deer movements within the corridor. We recommend continued monitoring of the US 1 Highway project is imperative in determining the long-term effects of highway improvement to Key deer permeability within the corridor area.

Deer-vehicle collisions and crossing events

We found a decrease in deer-vehicle collisions within the project area following the completion, which agrees with other studies (Reed et al. 1982, Ludwig & Bremicker 1983, Clevenger et al. 2001). As is the case with many deer exclusionary fencing projects, 100% effectiveness (i.e. no deer inside the fence) was not achieved and impractical (Woods 1990, Putman 1997). We found the four experimental deer guards in combination with fencing were effective in reducing Key deer entry into the US 1 project area. With the understanding that some deer will cross into the roadway (we observed eight crossing during the study period), strategies for safe removal of incidental deer from the fenced section becomes necessary. This became evident after one deer was euthanized after receiving a severe fence-induced wound during its removal. We recommend side swing gates strategically placed at fence point ends to facilitate the removal of deer in the event of entry into project areas. Swing gates allowed for the easy removal of deer from fenced areas of our project.

Underpass use

Previous underpass studies (Reed et al. 1975, Ward 1982, Foster & Humphrey 1995, Clevenger & Waltho 2000, Ng et al. 2004) have documented wildlife use of highway underpasses. An even more challenging question is the number of animals that do not use underpasses. The unique features of our study area and the camera transect layout allowed us to determine a relative estimate of the number of deer that did not use the underpasses (see Figs. 2, 4 and 5). The change in underpass exposures over time suggests there may be presence of an acclimation period, though we caution the reader due to the limited data collection (< 2 years of data). Other studies report that similar acclimation periods exist with newly-placed wildlife crossing structures, some requiring up to five years (Reed et al. 1975, Clevenger & Waltho 2003). Although the increase in underpass use may simply be due to an increase of Key deer movements, this explanation is not supported because the number of exposures within the corridor actually decreased 7-12 months post-project (see Fig. 5). Future monitoring of underpass use is recommended in determining whether deer acclimation to the project area is actually occurring. In comparing Key deer overall underpass use (see Fig. 5), south underpass use was greater than north underpass use. We attribute this differential underpass use to the lack of alternative crossings in the southern region compared to the north where the fencing project ends < 200 m from the north underpass. For the latter, we observed radio-collared deer simply going around the project area in some cases.

Conclusions

At a large scale, radiotelemetry data indicate the US 1 project has the potential to maintain deer movements between surrounding Key deer habitats. The camera data suggests Key deer may become acclimated to the underpasses at about six months. However, longer monitoring will help to verify more accurate trends in use (Clevenger & Waltho 2003). Ultimately, future demographic and genetic studies will determine the effectiveness of the project in maintaining connectivity for the Key deer. Wildlife managers and transportation planners should anticipate an acclimation period, which is likely to vary by species (Reed et al. 1975, Waters 1988, Opdam 1997) when assessing animal movements associated with wildlife crossings. At a smaller (within-corridor) scale, radiotelemetry and camera data suggest that changes in movement patterns occurred within the BPK corridor as a result of highway improvements. Although full BPK corridor crossings were of greatest concern, the potential for restricted movement within the corridor should not be ignored. Wildlife managers and transportation planners should make efforts to improve and/or maintain movements within corridors. In the case of Key deer, expanding and maintaining vegetative clearings along roadsides and reducing and/or eliminating other obstacles to movement (e.g. fill canals), when possible, can increase movements. Another possibility would be to expand the underpasses or add additional underpasses to facilitate movements. Such management practices can ultimately influence overall corridor connectivity within the landscape for species of concern like the Florida Key deer. Ultimately, deer guards in combination with fencing and underpasses seems to have been effective at reducing deer access into fenced segments of US 1 with no compromise of human safety (i.e. no reported human deer guard accidents). As more deer-vehicle collision issues develop in other suburban-type habitats, restricting deer access without interfering with human activities will become more important. The US 1 project demonstrates one design for addressing these issues. Perhaps of greatest importance is to continue monitoring the project (Clevenger & Waltho 2003, 2005) for potential negative effects toward Key deer movements and population connectivity within the natural corridor on BPK.

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