

# From the Field: Changes in ranges of Florida Key deer—does population density matter?



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**Abstract** The relationship between population density and range size has long been debated. While many studies have documented varying responses in range size to changes in population densities, most have been the result of experimental manipulation. We examined the effects of long-term density changes in Florida Key deer (*Odocoileus virginianus clavium*) on range and core-area sizes. We radiocollared Key deer as part of 2 separate research projects conducted December 1968–June 1972, and January 1998–December 2001. We used a total of 96 (females,  $n=62$ ; males,  $n=34$ ) and 163 (females,  $n=88$ ; males,  $n=75$ ) radiocollared Key deer to calculate annual and seasonal ranges and core areas, respectively. Season and age were not important factors in describing ranges and core areas of Key deer, while sex and period (early vs. current study) were important. On average, male annual ranges ( $\bar{x}=221$  ha, current;  $\bar{x}=388$  ha, early) were greater than female annual ranges ( $\bar{x}=42$  ha, current;  $\bar{x}=101$  ha, early), which might explain higher male mortality due to roadkills. Early ranges and core areas were greater ( $\approx 2\times$ ) than current ranges and core areas. We suggest that increased deer densities may have resulted in a decrease in Key deer ranges. Other factors influencing changes in Key deer ranges included increased habitat quality and Key deer domestication over the last 30 years.

**Key words** annual ranges, density effects, Florida Key deer, *Odocoileus virginianus clavium*, seasonal ranges, urban development, urban white-tailed deer

Understanding the relationship between density and range size in some species is essential for interpreting ecosystem function. A positive relationship could magnify the effects of an herbivore, carnivore, or disease vector as density increases, whereas a negative relationship could diminish those impacts (Anderson and May 1979, Hudson et al. 2002). Furthermore, the relationship between density and range size dictates the spatial scale and intensity of an individual's influence. For example, a positive relationship between density and range size would result in less intense impacts on larger

scales (e.g., disease transmission), whereas a negative relationship would create disproportionately intense impacts on smaller scales (e.g., herbivory).

Several studies suggest that range size of white-tailed deer (*Odocoileus virginianus*) negatively correlated with density (Bridges 1968, Smith 1970, Henderson et al. 2000, Lesage et al. 2000), whereas other studies suggest a positive relationship (Tierson et al. 1985, McNulty et al. 1997, Kilpatrick et al. 2001). Contradictory results reflect the complex spatial and temporal interactions between density, habitat quality, intraspecific competition,

and deer behavior. Two competing hypotheses commonly proposed in the literature include 1) a reduction in density *increases* deer ranges due to increased dispersal and available resources (“gas-molecule” hypothesis, McNulty et al. 1997) or 2) a reduction in density *decreases* deer ranges due to philopatric behavior (Tierson et al. 1985, Kilpatrick et al. 2001). In the case of urban white-tailed deer, understanding the relationship between density and range size is important, for example, in predicting the effectiveness of herd-reduction treatments (i.e., trap-and-removal programs, lethal methods) (Henderson et al. 2000). Previous studies (McNulty et al. 1997, Henderson et al. 2000, Kilpatrick et al. 2001) on urban white-tailed deer are a result of range-size changes immediately (1–2 years) following reductions in herd size due to hunting or trapping. Intense, immediate hunting or trapping pressure could have altered deer behavior, explaining the mixed results observed in other studies (Tierson et al. 1985, McNulty et al. 1997, Henderson et al. 2000, Kilpatrick et al. 2001). We propose that density change instigated by anthropogenic factors in a system (i.e., hunters and trappers) might occur at different rates and have different impacts than density change instigated by natural or internal factors like gradual changes in forage and cover availability. In either case, potential temporal interactions require further investigation of herd-reduction efforts and their effect on deer density over longer periods (Henderson et al. 2000).

We evaluated changes in the ranges of the endangered Florida Key deer (*O. v. clavium*) from 1968–2001. Key deer are the smallest subspecies of white-tailed deer in the United States and endemic to the Florida Keys on the southern end of peninsular Florida (Hardin et al. 1984). Approximately 75% of the overall deer population is found on 2 islands—Big Pine and No Name keys (Lopez 2001, Lopez et al. 2003). Key deer were radiomarked as part of 2 separate field studies (1968–1972, hereafter referred to as the early study; 1998–2001, hereafter referred to as the current study), which offered a unique opportunity to evaluate changes in Key deer ranges with a gradual population increase. Lopez et al. (2004) reported the Key deer population on these 2 islands increased 240% between the current and early studies (population estimate in 1971 = 201 deer, 2001 = 482 deer). Further, few studies (Silvy 1975) have evaluated Key deer ranges and core areas of this endangered deer population, with no range studies in recent

years. Thus, our study objective was to evaluate changes of Key deer annual and seasonal ranges and core areas following a gradual population increase (1968–2001).

## Study area

The Florida Keys are a chain of small islands approximately 200 km in length extending southwest from peninsular Florida. Big Pine (2,548 ha) and No Name (461 ha) keys are within the boundaries of the National Key Deer Refuge (NKDR), Monroe County (Lopez 2001). Soils varied from marl deposits to bare rock of the oolitic limestone formation (Dickson 1955). Typically, island areas near sea level (maritime zones) were comprised of red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*) forests. With increasing elevation, maritime zones transitioned into hardwood (e.g., gumbo limbo [*Bursera simaruba*], Jamaican dogwood [*Piscidia piscipula*]) and pineland (e.g., slash pine [*Pinus elliottii*], saw palmetto [*Serenoa repens*]) upland forests, with vegetation intolerant of salt water (Dickson 1955, Folk 1991). Approximately 24% of native vegetation areas were developed in the last 50 years (Lopez 2001).

## Methods

We captured Key deer as part of 2 separate research projects conducted December 1968–June 1972 (Southern Illinois University-Carbondale [SIU], Silvy 1975), and January 1998–December 2001 (Texas A&M University [TAMU], Lopez 2001) on Big Pine and No Name keys. We captured deer with portable drive nets (Silvy et al. 1975), drop nets (Lopez et al. 1998), or by hand (Silvy 1975). We physically restrained deer after capture, with an average holding time of 10–15 minutes (no drugs were used). We recorded sex, age, capture location, body weight, radio frequency, and body condition prior to release. We aged deer as fawns (<1 year), yearlings (1–2 years old), and adults (>2 years old) (Lopez 2001).

We marked Key deer with plastic neck collars (8 cm wide, primarily females of all age-classes), leather antler collars (0.25 cm wide, yearling and adult males only), or elastic expandable neck collars (3 cm wide, primarily male fawns/yearlings) (Silvy 1975, Lopez 2001). A battery-powered mor-

tality-sensitive radiotransmitter (425–450 g for plastic neck collars, 15–20 g for elastic collars [AVM Electronics Corporation, Champaign, Ill., 1968–1972]; 100–110 g for plastic neck collars, 10–20 g for antler transmitters and elastic collars [Advanced Telemetry Systems, Isanti, Minn., 1998–2000]) was attached to collar material. In addition, each animal captured was ear-tattooed (Silvy 1975). Methods used in the capture and handling of Key deer in the current study were approved by the TAMU Animal Care Committee (2002-139). State approval was not required for the first study, but animals were handled in the same manner.

Methods used to collect radiotelemetry locations were identical in both studies. We monitored radio-collared deer 6–7 times per week at random intervals (24-hour period was divided into 6 4-hour segments; we randomly selected one 4-hour segment and located all deer during that time [Silvy 1975, Lopez 2001]). We determined deer locations via homing (approximately 15% were visuals) [Silvy 1975, White and Garrott 1990:42, Lopez 2001] and entered them into a Geographical Information System (GIS) using ArcView (Version 3.2) and Microsoft Access (Version 97).

We calculated Key deer ranges (95% probability area) and core areas (50% probability area) using a fixed-kernel home-range estimator (Worton 1989, Seaman et al. 1998, 1999) with the animal movement extension in ArcView (Hooge and Eichenlaub 1999). We defined *ranges* as 95% probability areas and *core areas* as 50% probability areas determined from radiolocations. We used calculation of the smoothing parameter (kernel width) as described by Silverman (1986) in generating kernel range estimates.

We calculated annual ranges (ha) and core areas (ha) by sex, age, and period (early, current). We used only deer with  $\geq 175$  locations to calculate annual estimates. We calculated seasonal ranges (ha) and core areas (ha) by season, sex, age, and period (early, current). We defined seasons as winter (January–March, pre-fawning season), spring (April–June, fawning season), summer (July–September, pre-breeding season), and autumn (October–December, breeding season) (Silvy 1975). We used only deer with  $\geq 50$  locations in calculating seasonal ranges as recommended by Seaman et al. (1999). We tested differences in ranges and core areas using an ANOVA, followed by Tukey's HSD for multiple comparisons to separate

means when  $F$ -values were significant ( $P \leq 0.05$ , Ott 1993).

## Results

### Ranges

We used a total of 96 (female adult,  $n=51$ ; female yearling,  $n=11$ ; male adult,  $n=26$ ; male yearling,  $n=6$ ; male fawn,  $n=2$ ; current,  $n=65$ , early  $n=31$ ) and 163 (female adult,  $n=57$ ; female yearling,  $n=21$ ; female fawn,  $n=10$ ; male adult,  $n=42$ ; male yearling,  $n=18$ ; male fawn,  $n=15$ ; current,  $n=109$ , early  $n=54$ ) radiocollared Key deer to calculate annual and seasonal movements, respectively. The average number of locations used to calculate seasonal ranges and core areas was 76 (SD = 14, range = 50–124), while the average number of locations used to calculate annual ranges and core areas was 242 (SD 42, range = 175–380).

Sex and period were important (range,  $F_{1,2} = 49.81, 8.45, P < 0.004$ ; core area,  $F_{1,2} = 28.38, 4.02, P < 0.047$ ) in describing Key deer annual ranges and core areas while age was not important (range,  $F_2 = 0.16, P = 0.850$ ; core area,  $F_2 = 1.38, P = 0.255$ ; Figure 1). In general, male annual ranges ( $\bar{x} = 221$ –388 ha) were greater than female annual ranges ( $\bar{x} = 42$ –101), and early ranges ( $\bar{x} = 101$ –388 ha) were greater than current ranges ( $\bar{x} = 42$ –221 ha) (Figure 1).

For seasonal ranges, we also found that sex and period were important (range,  $F_{1,3} = 85.89, 16.36, P < 0.001$ ; core area,  $F_{1,3} = 55.39, 9.48, P < 0.002$ ) in describing Key deer seasonal ranges and core areas while season and age were not important (range,  $F_{1,3} = 2.54, 2.47, P > 0.056$ ; core area,  $F_{1,3} = 1.94, 1.02, P > 0.123$ ; Figure 2). In general, male seasonal ranges

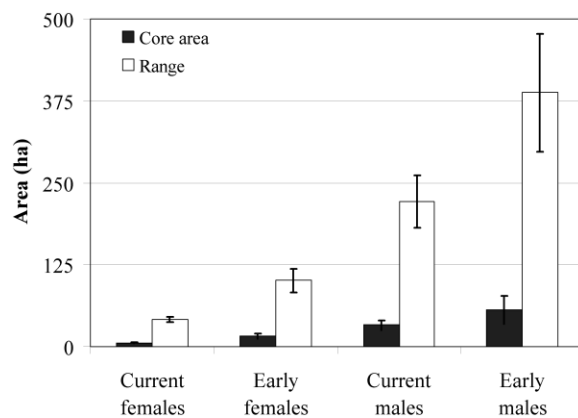


Figure 1. Florida Key deer annual ranges (mean 95% range and 50% core areas, SE, ha) by sex and period, Big Pine Key, 1968–1972 and 1998–2001.

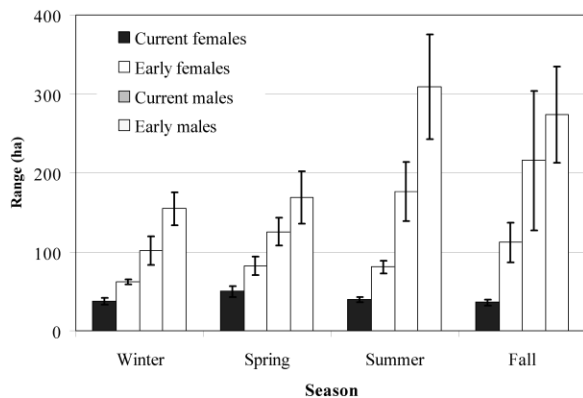


Figure 2. Florida Key deer seasonal ranges (mean 95% probability area, SE) by sex and period, Big Pine Key, Florida, 1968–1972 and 1998–2001.

( $\bar{x}$  = 102–309 ha) were greater than female seasonal ranges ( $\bar{x}$  = 36–112 ha), and early deer ranges ( $\bar{x}$  = 79–275 ha) were greater than current deer ranges ( $\bar{x}$  = 34–172 ha) (Figure 2). Because we found that ranges and core areas were influenced by sex in our analyses, we compared period, age, and season for each sex separately. For female seasonal ranges, we found that period was important (range,  $F_1 = 41.71$ ,  $P < 0.001$ ) while age and season were not (range,  $F_{2,3} = 2.35$ , 1.80,  $P > 0.098$ ). For female seasonal core areas, we found that period and age were important (core area,  $F_{1,2} = 12.78$ , 7.41,  $P < 0.001$ ) while season was not (core area,  $F_3 = 1.56$ ,  $P = 0.200$ ). Male seasonal ranges differed among period, age, and season (range,  $F_{1,2,3} = 8.18$ , 3.28, 2.67,  $P < 0.049$ ); however, only period was an important variable (core area,  $F_1 = 5.97$ ,  $P = 0.016$ ) in describing male core areas. Male summer and fall ranges were greater ( $\bar{x}$  = 205 and 238 ha, respectively) compared to winter and spring ( $\bar{x}$  = 126 and 140 ha, respectively, Figure 2).

## Discussion

As expected, we found that male ranges and core areas were significantly larger than female ranges and core areas (Figure 1). Larger male ranges have been reported in numerous white-tailed deer studies (Gavin et al. 1984, Mott et al. 1985, Tierson et al. 1985, Beier and McCullough 1990). In addition, in a review of reported white-tailed ranges, Demarais et al. (2000) concluded that average male ranges were nearly double those of female ranges. Similar results were found in our study, where Key deer male ranges were 4–5 times greater than female

ranges. Lopez et al. (2003) reported that survival for females was higher than male survival and that approximately 50% of Key deer mortality was attributed to road mortality. Our study supports the premise that larger male ranges increase the risk of male Key deer to deer–vehicle collisions (Lopez et al. 2003). We also found seasonal differences in male Key deer ranges, with ranges increasing during the pre-breeding and breeding season (Figure 2). Further, our study supports findings from previous studies of white-tailed deer (Silvy 1975, Tierson et al. 1985, Beier and McCullough 1990, Lopez 2001) that report increased male ranges during the breeding season.

We observed decreased Key deer ranges and core areas for both sexes from 1968–2001. We attribute the decrease in Key deer ranges to changes in population density, habitat quality, and deer–human interactions. First, our study suggests that range size might be negatively correlated with deer densities (Bridges 1968, Smith 1970, Marchinton and Hirth 1984, Henderson et al. 2000, Lesage et al. 2000). We hypothesize that as Key deer densities increased, ranges decreased due to limited space and possibly greater reproductive opportunities in smaller areas. The complex interactions between ranges and density, however, do not preclude other factors that may explain the decrease in deer ranges. Folk and Klimstra (1991) suggested that Key deer domestication and supplemental feeding would lead to smaller range sizes. Since 1970 nearly 24% of natural areas were developed on Big Pine and No Name keys along with a 10-fold increase in the human population (Lopez 2001). A reduction of Key deer ranges also might be explained by increased habitat quality due to a greater amount of “edges,” and localized food (i.e., ornamental plants, supplemental feeding) and water (i.e., bird baths, pet dishes) resources (Lopez 2001). Collectively, we propose that changes in population density along with increased habitat quality and Key deer domestication over the last 30 years have resulted in decreased Key deer ranges.

## Management implications

Contradictory results in white-tailed deer studies illustrate the complex spatial and temporal interactions between density, habitat quality, and intraspecific competition (Tierson et al. 1985, McNulty et al. 1997, Henderson et al. 2000, Lesage et al. 2000, Kilpatrick et al. 2001). Our study suggests a nega-

tive relationship between these factors and range sizes. For wildlife managers, understanding this relationship is important in addressing potential impacts of high densities to habitat quality or in understanding the function of disease transmission. In the short term, a positive relationship in deer density and ranges may occur (Tierson et al. 1985, Kilpatrick et al. 2001); however, in the long term this relationship may change and become negative as deer populations acclimate to environmental changes. Our study suggests that ultimately a negative response between range size and deer density would be expected. For urban white-tailed deer managers, understanding such an expected response is important in, for example, the planning of herd-reduction efforts particularly in determining the frequency of such treatments.

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