Key deer fawn response to urbanization: is sustainable development possible?

M. Nils Peterson, Roel R. Lopez, Philip A. Frank, Brad A. Porter, and Nova J. Silvy

Abstract Assuming that a finite biosphere can support infinite development seems logically indefensible, yet the concept of sustainable development has become a dominant conservation paradigm. The story of the endangered Florida Key deer (*Odocoileus virginianus clavium*) appears to support the legitimacy of sustainable development because Key deer numbers have increased 240% since 1970 while at the same time human numbers in their habitat increased nearly 10-fold. Because fawn mortality is considered the primary density-dependent factor regulating cervid populations as they approach *K*-carrying capacity, we hypothesized that changes in fawn demographics could elucidate the fallacy in assuming that development was sustainable on Big Pine Key. We determined and compared survival and range sizes for Key deer fawns between 1968–1972 (early urban development) and 1998–2002 (post-urban development). Fawn ranges (95% probability area, 149 to 33 ha) and core areas (50% probability area, 25 to 6 ha) decreased during this period of development while 6-month survival increased (0.47 to 0.96). All fawn mortality was due to anthropogenic causes; the positive relationship between fawn survival and development may be a function of isolating fawns from anthropogenic mortality. If this is true, the relationship is not sustainable because as ranges continue to shrink, they eventually will lack sufficient resources to support a fawn.

Key words fawns, Florida, Key deer, *Odocoileus virginianus clavium*, range, survival, sustainable development, urban deer

Increasing human population and demands for improved standards of living, combined with limited habitat for wildlife, lead to conflict over economic, political, and social costs associated with use and preservation of the natural environment (Peterson et al. 2002). Assuming that a finite biosphere can support infinite growth of the human enterprise seems logically indefensible. Nevertheless, we have embraced the concept of sustainable development (Peterson 1997). Although this concept has no universally accepted definition, its application in wildlife management has taken the form of substituting technological advances and creative management for dwindling areas of suitable habitat. Governmentally sanctioned processes, such as habitat conservation planning, legitimize efforts to support development and maintain sustainable wildlife populations.

Endangered-species management provides a focal point for clashes between sustainability and development because it creates a rare situation in which sustainability of wildlife populations has legitimate precedence over development. The exponential growth of habitat conservation plan-

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ning (Allison 2002) represents either an attack on this rare bastion for sustainability or a means to realize truly sustainable development. At first glance, the story of the endangered Florida Key deer (*Odocoileus virginianus clavium*) supports the legitimacy of the latter interpretation.

Urban development in the Keys has been a concern in the recovery and management of Key deer for the last 3 decades (Klimstra et al. 1974). Since 1970 the human population has increased nearly 10-fold on Big Pine Key. In 2000 the resident population was 5,000 people, plus an influx of 1,000-1,500 tourists during winter (Folk 1991, Lopez et al. 2003, United States Census Bureau 2000). Scientists suggested that development and urbanization of Key deer habitat would lead to higher rates of deer-vehicle collisions (Folk and Klimstra 1991) and disease transmission (Nettles et al. 2002). Comparisons to baseline data (1968-1972) indicate that urbanization has had little effect on adult Key deer survival (Lopez et al. 2003), and during this period of massive development, the Key deer population grew nearly 240% (Lopez 2001).

With the exception of the Columbian subspecies (*O. v. leucurus*; Ricca et al. 2002), white-tailed deer management lends credence to the concept of sustainable development. White-tailed deer have rebounded from near extirpation in the early 1900s to overabundance, in many cases, during a period of unprecedented urban and suburban expansion (McShea et al. 1997). However, the relationship between urbanization and Key deer population growth probably operates with diminishing returns (Lopez 2001). Growing numbers of Key deer and the reduction in "usable" space (Guthery 1997) caused by development have both contributed to higher densities. We hypothesized that this would lead to smaller fawn ranges and higher mortality.

Key deer drinking from a puddle in the Big Pine Key Lions Club parking lot. Photo by N. Peterson.

Fawn mortality is considered a primary density-dependent mechanism regulating cervid populations as they approach *K*-carrying capacity (McCullough 1979, Clutton-Brock et al. 1982, Sams et al. 1996), so changes in fawn mortality and range size should manifest themselves before the population reaches carrying capacity. Little demographic information exists for Key deer fawns (<6 months of age; Lopez et al. 2003), so we determined range size and survival for early urban development (1968-1972) and post-urban development (1998-2002) fawns. Our objective was to determine whether higher Key deer density led to smaller ranges and higher mortality for Key deer fawns.

Study area

Florida Key deer, listed as an endangered subspecies of white-tailed deer in 1967, are endemic to the Florida Keys on the southern end of peninsular Florida (Hardin et al. 1984). Key deer occupied 20-25 islands within the boundaries of the National Key Deer Refuge (NKDR), with approximately 65% of the overall deer population on Big Pine Key (12,548 ha; Lopez 2001, Lopez et al. 2003). Big Pine Key served as a population source for the Key deer metapopulation because permanent freshwater sources were not available on other keys. All data presented in this paper were collected on this island.

Typically, island areas near sea level (maritime zones) were comprised of red mangrove (*Rhisophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erecta*) forests. With increasing elevation, maritime zones transitioned into hammock (e.g., Gumbo limbo [*Bursera simarub*], Jamaican dogwood [*Piscidia piscipulaa*]), and pineland (e.g., slash pine [*Pinus elliottii*], saw palmetto [*Serenoa repens*]) upland forests intolerant of salt water (Dickson 1955). Approximately 24% of the native vegetation has been converted for residential or commercial uses since 1955 (Lopez 2001).

Methods

We live-trapped and radiocollared Key deer fawns between 1968-1972 and between

1998–2002. Fawns were captured using portable drive nets (Silvy et al. 1975, Peterson et al. 2003), and hand-held dip nets (Silvy 1975). We used physical restraint to hold fawns after capture, with an average holding time of 5–10 minutes (no drugs were used). We recorded sex, capture location, body weight, radio frequency, and body condition for each fawn prior to release. We fitted each fawn with an expandable, breakaway, battery-powered, mortality-sensitive radiotransmitter collar (15 g, Advanced Telemetry Systems Inc., Isanti, Minn.).

We determined fawn locations via homing (White and Garrott 1990, Lopez 2001) 6–7 times per week at random intervals (24-hour period was divided into 6 equal 4-hour segments; 1 [4-hour] segment was randomly selected, and during that time all deer were located [Silvy 1975]). We calculated fawn (<6 months) 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 (Hooge and Eichenlaub 1999). We calculated the smoothing parameter as described by Silverman (1986) to generate kernel range estimates. We tested differences in ranges and core areas using a t-test where values were considered significant at $P \leq 0.05$ (Ott and Longnecker 2001).

We monitored radiocollared fawns for mortalities 6–7 times per week, and immediately followed mortality signals by walk-ins to determine cause of death from evidence at recovery sites. We necropsied all carcasses using procedures described by Nettles (1981). Animals were censored from the data set after the last known encounter when radios failed (Pollock et al. 1989).

Peak fawning for Key deer occurred in May (Hardin 1974), and we calculated fawn survival through November. Thus, our 6-month survival estimates were conservative because they may have reflected mortalities occurring during the first 7 months. We analyzed survival data using the Kaplan-Meier model in the program Ecological Methodology (Krebs 1999). We compared fawn survival during early urban development (1968–1972) and post-urban development (1998–2002) using the log-rank test (Pollock et al. 1989). Sexes were pooled due to small sample size (White and Garrott 1990), with tests of the null hypothesis (equal survival) being conducted at $P \leq 0.05$.

Results

We captured and radiomarked 53 Key deer fawns during both studies (historic: 7 females, 19 males; current: 8 females, 19 males). No fawns died during capture or from capture-related mortality. Current fawn ranges (95% probability areas) decreased significantly since the early urban development period (149 to 33 ha, $t=2.91$, 22 df, $P<0.01$). Fawn core areas (50% probability areas) decreased in size from 25 to 6 ha since the historic study, and current core areas were significantly smaller than historic core areas ($t=2.30$, 22 df, $P=0.032$; Figure 1).

We tracked radioed fawns for 198 total months (9 deaths, 23 censors, 166 survivals), and all censored

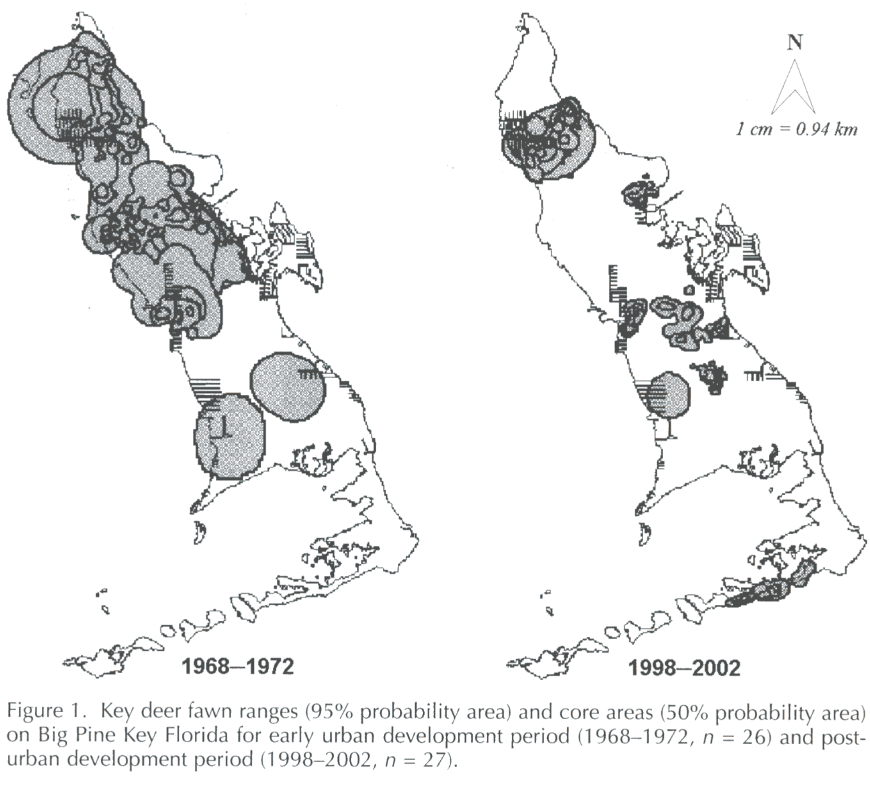

Figure 1. Key deer fawn ranges (95% probability area) and core areas (50% probability area) on Big Pine Key Florida for early urban development period (1968–1972, n = 26) and post-urban development period (1998–2002, n = 27).

months reflected radio malfunction or a lost signal. We did not detect a difference between early urban development survival (0.47) and post-urban development fawn survival (0.96; $\chi^2=1.720$, 1 df, $P=0.196$). Censoring fawns that drowned from the sample did not increase fawn survival ($\chi^2=2.270$, 1 df, $P=0.147$).

Drowning in ditches and death due to collisions with vehicles were the only causes of fawn mortality in our study. Drowning (6 mortalities; early urban development study) occurred in April and May, while deer vehicle-collisions (2 early urban development; 1 post-urban development) occurred in September and October. No "natural" fawn mortality has been documented by researchers or reported to the United States Fish and Wildlife Service (USFWS). All recorded fawn mortality has been human-related (i.e., dog mauling, vehicle collision, entanglement in fencing or netting, or drowning in canals and ditches).

Discussion

The decrease in fawn range-size since the early urban development study supports our hypothesis that higher deer densities would lead to smaller ranges. However, the survival comparison did not support our contention that smaller range size would equate to higher mortality. This counterintuitive result could have several explanations. Although post-development survival was higher, censoring drowning yielded similar pre- and post-urban development mortality. A maze of 30-cm-wide and 1-2-m-deep ditches was dredged through low-lying areas on Big Pine Key in the 1950s to facilitate saltwater intrusion into freshwater holes serving as mosquito (*Ochlerotatus taeniorhynchus*) breeding sites (Hardin 1974). After the historic study of Key deer fawn survival (Silvy 1975), USFWS personnel manually filled ditches connecting 3 freshwater wetlands to the ocean, and siltation over the last 30 years partially filled the remaining ditches. Within the wetland areas ditches were completely filled with silt and organic matter, but in open, rocky areas ditches were only about 20% filled. This may have contributed to improved fawn survival. A 3-month study (March-May 1999) failed to find any fawns or fawn remains in ditches (USFWS, unpublished data), and no fawn drowning occurred in our post-urban development study.

Neonatal Key deer fawn immediately after capture. Photo by W. Peterson.

The role of cover for Key deer fawn survival also may explain why a 75% reduction in range size was not associated with increased mortality. Cover may be less critical for Key deer fawns than for fawns of other white-tailed deer subspecies. Predators such as coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) implicated in fawn mortality elsewhere (Ricca et al. 2002) are absent in the Key deer range, so predation pressure is slight if it exists at all. While abandonment, disease, and malnutrition probably influence fawn mortality, we found no evidence of fawn mortality induced by these factors during our study.

Factors associated with Key deer fawn mortality (i.e., cars, domestic dogs [under leash laws], fences, and soccer nets) do not move into natural habitats on their own volition. Because Key deer fawns are not depredated in a traditional sense, we propose that they may expose themselves to mortality hazards in urban areas as they move through their range. Therefore, the fact that smaller ranges are not associated with increased fawn mortality might be a function of how much urban area is included in the typical fawn's range. Higher deer density, smaller ranges, and decreased movement may isolate some fawns from anthropogenic mortality. This process probably was enhanced by the infilling of previously suitable habitat within subdivisions (Lopez 2001), rather than the clearing of natural areas. Infilling of subdivisions and smaller range size may mask the increasing impacts of development by forcing fawns out of urban areas where mortality is highest and reducing the probability that an individual fawn will be exposed to fixed hazards like soccer nets, canals, and roads. Further, lower speed limits and increased awareness of Key deer management within the community (Peterson et al. 2002) may have reduced the proportion of fawns killed in vehicle collisions even with the higher traffic levels associated with development.

Freshwater (Hardin 1974) and upland areas (Lopez 2001) are considered limiting factors for the Key deer. In the case of the latter, Lopez (2001) reported that upland areas (i.e., pinelands, hammocks, and developed areas, areas >1 m above mean sea level) were important to Key deer, whereas lowlands (i.e., mangroves and buttonwood forests, areas <1 m above mean sea level, tidally influenced) were less important. In the last 30 years, urban development within the Key deer range has provided both of these resources. First, development has provided a reliable source of fresh water for Key deer in the form of birdfeeders, pet dishes, ornamental ponds, and water supplementation by residents. Second, before the enactment of wetland protection laws, early development (1950–1970s) increased the total amount of upland habitat by converting lowlands to "uplands" in the form of subdivisions (Lopez 2001). However, recent development (1980s–present) is restricted to upland areas and infilling of subdivisions. If this trend continues, it may erase the upland habitat gains made during early development years. Fawn survival may remain high for a short time, but eventually shrinking ranges will cease to provide sufficient sustenance. Nettles et al. (2002) reported the Key deer population was at or near carrying capacity based on observed abomasal parasite counts. If this assessment was accurate, development is no longer sustainable and the relationship between fawn survival and development will be reversed.

Curious Key deer fawn in Port Pine Heights subdivision. Photo by W. Peterson.

Anthropogenic changes on Big Pine Key are blamed, correctly, for the historical plight of Key deer (Lopez 2001). Although those changes also are considered the greatest danger to Key deer population viability (Lopez et al. 2003), our results indicate that careful management and conscientious driving habits of residents on these islands has allowed a concomitant increase in fawn survival and urban development over the last 30 years. We suggest that development and fawn survival, however, cannot be positively correlated once carrying capacity is reached. This conclusion seems intuitive for Key deer because they live on small islands. Wise management practices can only facilitate the co-occurrence of development and wildlife conservation for a limited time.

Management implications

Fawn mortality is the primary density-dependent factor regulating cervid populations, and Key deer fawn survival has increased or remained stable, so managers may assume that historical development on Big Pine Key has not damaged sustainability of the Key deer population. This does not, however, imply that development is sustainable on Big Pine Key. When development is defined as expansion of commercial and residential areas, it is limited by the size of the island on which it occurs. Further, since habitat loss from development leads to higher Key deer density and smaller fawn ranges, it will damage Key deer sustainability when ranges become too small to provide sustenance for fawns. We maintain that a fulcrum exists where just a few more houses will reverse the positive relationship between development and sustainability for the Key deer population. Development in the Keys crossed that fulcrum years ago regarding wildlife species less tolerant of development, such as the endangered Lower Keys marsh rabbit (*Sylvilagus palustrus hefneri*) and Key Largo woodrat (*Neotoma floridana smalli*; Faulhaber 2003, McCleery 2003). Since Key deer probably are at the threshold (Nettles et al. 2002), managers should in the future avoid development that involves expansion of urban areas.

Property-rights advocates are unlikely to accept limits on development (Peterson et al. 2002) and will argue for sustainable development, particularly in areas where its logical fallacy is less obvious than on islands. Limits on development and eventually its cessation, however, are necessary for saving Key deer. Humans and Key deer are doing better with fewer natural resources, but neither species has a sustainable future unless development, defined as expansion, eventually stops.

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