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## Movements and Habitat Use of the Key Largo Woodrat

Robert A McCleery<sup>1,\*</sup>, Roel R. Lopez<sup>1</sup>, and Nova J. Silvy<sup>1</sup>

**Abstract** - We radio-collared and tracked 16 (10 female, 6 male) *Neotoma floridana smalli* (Key Largo woodrats) from March–November 2002 and recorded a total of 631 locations. The average monthly ranges of individual male and female woodrats were 4756 (95% CI = 2376–7136) m<sup>2</sup> and 2051 (95% CI = 1091–3011) m<sup>2</sup>, respectively. We found male and female ranges to be significantly different ( $P = 0.032$ ). Female ranges varied with season ( $P = 0.032$ ), while male ranges did not ( $P = 0.567$ ). Spring ( $P = 0.033$ ) and summer ( $P = 0.019$ ) ranges were significantly different between sexes. At two spatial scales, Key Largo woodrats showed a preference for young habitat with selection ratios of 6.3 and 6.7. Six female ranges overlapped an average of 49% and 2 males overlapped an average of 8%. No woodrats were recorded crossing a major road. Study results suggest that *N. f. smalli* prefer early succession hammock, male woodrats should be introduced separately, and a major road is a barrier to woodrat movements.

### Introduction

*Neotoma floridana smalli* Whitaker and Hamilton (Key Largo woodrat) is 1 of 5 subspecies of *N. floridana* Whitaker and Hamilton (eastern woodrat) found throughout the southeastern United States (Whitaker and Hamilton 1998). Like other eastern woodrats, *N. f. smalli* is nocturnal, forest dwelling, and known for the building of stick nests (Rainey 1956, USFWS 1999, Whitaker and Hamilton 1998). However, unlike other eastern woodrats, *N. f. smalli* is endemic to the tropical hardwood hammocks of the island of Key Largo, FL, and separated from other subspecies of eastern woodrat by at least 210 km (Greer 1978). *Neotoma floridana smalli* can be distinguished from woodrats found on mainland Florida by the size and shape of portions of their skulls (Sherman 1955). The Key Largo woodrat was federally listed as an endangered species in 1984 because of concerns over habitat loss and the impact of commercial development (USDOJ 1984). Since development began on Key Largo in the 1920s, 47% of the woodrats' habitat has been lost from the island, and most of what remains has been cleared, thinned, developed, and fragmented (Strong and Bancroft 1994). Since 1973, *N. f. smalli* has been confined to approximately 850 ha of remaining forest located on the northern end of Key Largo (Barbour and Humphrey 1982, USDOJ 1973). Greater than 90% of these 850 ha are within the bounds of 2 protected areas: Dagny Johnson Key Largo Hammock Botanical State Park and Crocodile Lake National Wildlife Refuge (Frank et al. 1997).

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Recent findings (McCleery et al. 2005, McCleery et al. 2006) have highlighted the Key Largo woodrats' decline over the last several decades. Recently, the woodrat population was estimated to be < 100 individuals (McCleery et al. 2005), and a population viability analysis (PVA) predicted a > 70% chance of extinction for *N. f. smalli* within the next 10 years if no management actions are taken (McCleery et al. 2005). To address these problems, the US Fish and Wildlife Service (USFWS) initiated a captive-breeding program. One of the primary goals of the program was to release captive-reared individuals into suitable native habitat (Dean 2003).

To effectively implement a reintroduction program and aid in the evaluation of the program, it is essential to obtain a basic understanding of Key Largo woodrat movements and habitat selection prior to release of captive breed individuals. Currently, little is known about the movements of the species, leaving managers with scarce information to make vital decisions on the reintroduction and recovery of this species. Previous studies (Hersh 1981, Sasso 1999) used trapping grids to generate estimates of *N. f. smalli* ranges and movements. However, the limitations and biases of these methods have been well documented (Sanderson 1966, Stickel 1954). Researching habitat selection of Key Largo woodrats presents additional problems. Published accounts of *N. f. smalli* habitat selection appear to contradict each other with some indicating that *N. f. smalli* prefer mature hammock (Barbour and Humphrey 1982, Brown 1978, Hersh 1978), while others suggest *N. f. samlli* use hammocks of varying degrees of succession (Goodyear 1985, Keith and Gaines 2002, Sasso and Gaines 2002), and a more recent studies states that *N. f. smalli* prefer early succession hammock (McCleery 2006). Compounding the problem is the fact that these previous woodrat habitat studies (Barbour and Humphrey 1982, Brown 1978, Hersh 1978, Goodyear 1985, Keith and Gaines 2002, McCleery et al. 2006) have used trapping to estimate habitat selection. This can potentially bias data because of differential susceptibility of capture for particular animals or segments of a population, and of the possibility of bait luring animals into habitats they might not frequent or inhabit (Litvaitis et al. 1996).

Using radio telemetry to estimate ranges, movements, and habitat selection can eliminate many of the biases created by estimated movements and habitat use through trapping (Litvaitis et al. 1996). Telemetry data can be used to determine the amount and type of habitat required for the reintroduction of captive reared woodrats. It can also be used to examine social interactions, range overlaps, and barriers to movement (White and Garrott 1990). Lastly, radio-telemetry data from Key Largo woodrats can provide baseline data needed to compare the movements of introduced woodrats to movements of resident individuals.

In this study, we used radio telemetry to: estimate the size of Key Largo woodrat ranges; determine the effects of sex, month, and season on range size; and examine range overlaps by sex. We also used radio telemetry to investigate *N. f. smalli* habitat selection and to determine if a road bisecting woodrat habitat presented a barrier to their movements.

## Methods

### Study area

Key Largo is the first and largest in a chain of islands (keys) that extend from the southern tip of the Florida mainland. Our study area on Key Largo (972 ha) included the hammocks and disturbed/developed areas found along a 14-km stretch of protected hardwood hammock forest on the northern third of the island (Fig. 1). The hardwood hammock habitat on the island of Key Largo is unique, with a high abundance of West Indian plants and trees (Strong and Bancroft 1994, USFWS 1999). Some common canopy trees found in Key Largo's hammocks include *Bursera simaruba* (L.) Sarg. (gumbo-limbo), *Metopium toxiferum* (L.) Krug & Urban (poison-wood), *Lysiloma bahamense* Benth. (wild tamarind), *Cocoloba diversifolia* Jacq. (pigeon plum), *Bumelia salicifolia* (L.) Sw. (willow bustic), and *Piscidia foetidissimum* (Jamaican dogwood). Common species in the hammock understory are *Eugenia* spp. (stoppers), *Gymnanthes lucida* Sw. (oysterwood), *Psychotria undata* Jacq. (wild coffee), and *Amyris elemifera* L. (torchwood).

### Movements

Key Largo woodrats were trapped throughout March–September 2002 on 60 randomly placed 1-ha grids. Upon capture, the woodrats were radio-tagged with 7-g radio collars (AVM Instrument Company, Colfax, CA) with mortality sensors (Model G3). The woodrats were tracked until their radios failed or the woodrat died. An effort was made to replace weak and dying radio collars when possible. The woodrats were located twice weekly during daylight hours (when woodrats are inactive) at their nesting sites and at least twice a week at night (when woodrats are active) during 1 of 3 random, 3-hour intervals (20:00–05:00). Locations of woodrats were determined via homing and triangulation (Samuel and Fuller 1996). Homed locations were recorded with a global positioning system (GPS; Magellan 315). We calculated triangulated locations from three or more bearings from known receiving stations (determined from a GPS) and generated XY-coordinate locations and error ellipses using Location of a Signal (LOAS; Ecological Software Solutions, Urnäsch, Switzerland), disregarding triangulated locations with error ellipses > 500 m<sup>2</sup>. We then mapped all telemetry locations on a geographical information system (GIS) to aid in the analysis of woodrat ranges, habitat selection, and barriers to movement.

We defined Key Largo woodrat ranges as the 2-dimensional area traversed by the woodrats during specified time intervals (month and season, White and Garrot 1990). We calculated the minimum number of telemetry locations necessary for the calculation of woodrat ranges using BIOTAS (Ecological Software Solutions, Urnäsch, Switzerland) to plot the total range area of individual woodrats versus the number of locations on the animal. We again used BIOTAS to determine 100% minimum-convex polygons (MCP) for the woodrats by month. From monthly MCP range sizes, we calculated average monthly ranges and seasonal ranges (averages from 3-month periods: spring = March–May; summer = June–August; fall = September–November). Differences in male and female average monthly

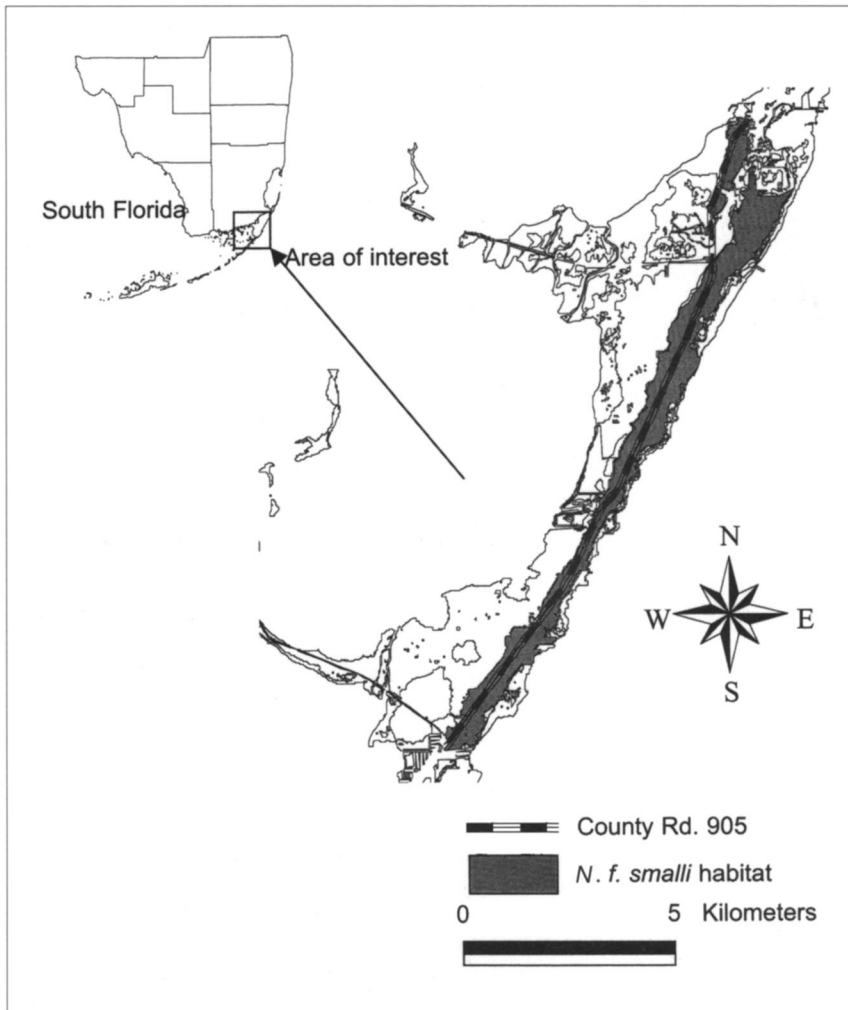


Figure 1. The northern third of the island of Key Largo, FL, *N. f. smalli* habitat and County Road 905.

and seasonal ranges were evaluated, and differences between seasonal ranges were evaluated for the entire population. Normally distributed data were analyzed with general linear models ( $P < 0.05$ ), and non-normal data with a Kruskal-Wallis test ( $P < 0.05$ ) (Ott 1993).

We calculated the percentage of range overlap between and within sexes from individuals tracked during similar time periods. Overlap was determined by dividing the amount of intersected area from 2 woodrats by the range area of each individual. We used ArcView (Environmental Systems Research Institute, Redlands, CA, version 3.1) and the ArcView animal movements extension (Version 2.2; Hooge and Eichenlaub 1999) to place monthly MCP ranges on the GIS database and determined the area of overlap using the ArcView geo-processing tool.

We added roads and digital ortho quarter quads (DOQQ) of north Key Largo to our GIS database to determine if woodrats were crossing County Road 905 and at what rate. We queried all telemetry locations recorded within 25 m of the road and determined the number of times consecutive locations were found on opposite sides of the road. Rates of crossing were calculated as the number of consecutive locations on opposite sides of the road divided by the number of locations within 25 m of the road. Mortalities from road kill were determined by examining recovered radio collars and the sites of mortality where the transmitters were located.

### **Habitat use**

We classified our study site into 4 hammock types: young hammock (disturbed after 1971; 106 ha), medium hammock (disturbed from 1940–1971; 331 ha), old hammock (disturbed before 1940; 408 ha), and urban/disturbed (paved, developed, or cleared hammock; 127 ha). Hammock types were identified from aerial photos, ground truthing, and previous vegetation studies (Ross et al. 1995), mapped in ArcView (Environmental Systems Research Institute, Version 3.1), and placed in the GIS database. All woodrat telemetry locations and MCP ranges already in the database were overlaid on top of hammock types to determine the number of locations and portions of MCP ranges found in each hammock type for each woodrat.

To describe Key Largo woodrat habitat preferences, we used habitat-selection ratios to compare habitat use to habitat availability (Lopez et al. 2004, Manly et al. 2000) on 2 spatial scales. Evaluating habitat use on differing spatial scales can help reduce biases introduced by defining what habitats are available to individual animals or animal population (Lopez et al. 2004, Porter and Church 1987). We calculated first-order selection (Johnson 1980) ratios ( $S$ ) for each woodrat by dividing the number of locations found in each habitat type by the total number of telemetry locations multiplied by the portion of each habitat type in the study area. Second-order habitat selection (Johnson 1980) ratios ( $S$ ) were

calculated by dividing the portion of habitat in each woodrat's range by the portion of each habitat type in the study area. To avoid calculation with numerous zeroes in the numerator, we added 0.001 to both the numerator and denominator (Lopez et al. 2004). Selection ratios were averaged and presented graphically with 95% confidence intervals ( $\pm 2$  standard errors). Selection ratios that are  $> 1$  suggest animals use the habitat more than expected, while those ratios  $< 1$  suggest that animals are avoiding those habitats.

## Results

### Movements

Sixteen Key Largo woodrats (10 female, 6 male) were radio-collared and tracked March–November 2002 for an average of 106 days of tracking for each woodrat. A total of 631 locations were recorded. From range area vs. location plots, we determined that at least 9 locations were necessary to calculate a woodrat range. The average monthly ranges of individual male and female woodrats were 4756 (95% CI = 2376–7136) m<sup>2</sup> and 2051 (95% CI = 1091–3011) m<sup>2</sup>, respectively (Table 1). We found male and female ranges to be significantly different ( $P = 0.032$ ). Female ranges varied with season ( $P = 0.032$ ), while male ranges did not ( $P = 0.567$ ). Spring ( $P = 0.033$ ) and summer ( $P = 0.019$ ) ranges were significantly different between sexes, and fall ranges were not significantly different ( $P = 0.111$ ). We were unable to calculate winter ranges due to inadequate sample sizes ( $< 4$  woodrat with adequate telemetry locations).

Six Key Largo woodrats were located within 25 m of County Road 905 on 38 occasions, but we recorded no woodrat with locations on both

Table 1. Average MCP monthly and seasonal *N. F. smalli* range sizes (m<sup>2</sup>) by sex, Key Largo, FL.

Range	Time period	Sex	n		Mean	Median	SE
			Woodrats	Monthly avg.			
Monthly average	All records	Female	10		2051	1245	480
		Male	6		4756	3900	1190
		Both	16		3065	2542	615
Seasonal <sup>A</sup>	Spring	Female		9	1126	480	427
				11	1076	677	344
				17	2414	2212	408
	Summer	Male		3	8060	3219	5185
				3	9945	8632	4454
				5	3979	3606	1196
	Fall	Both		12	2859	1294	1463
				14	2976	749	1321
				23	2744	2216	407

<sup>A</sup>Spring = March–May; Summer = June–August; Fall = September–November.

sides of the road. From 6 woodrat mortalities, none were found on or near the road.

### Habitat use

We used 631 locations from 16 woodrats to calculate selection ratios with an average of 40 (SD= 25, range = 11–107) locations per animal. At both spatial scales, woodrats showed a preference for young habitat, with

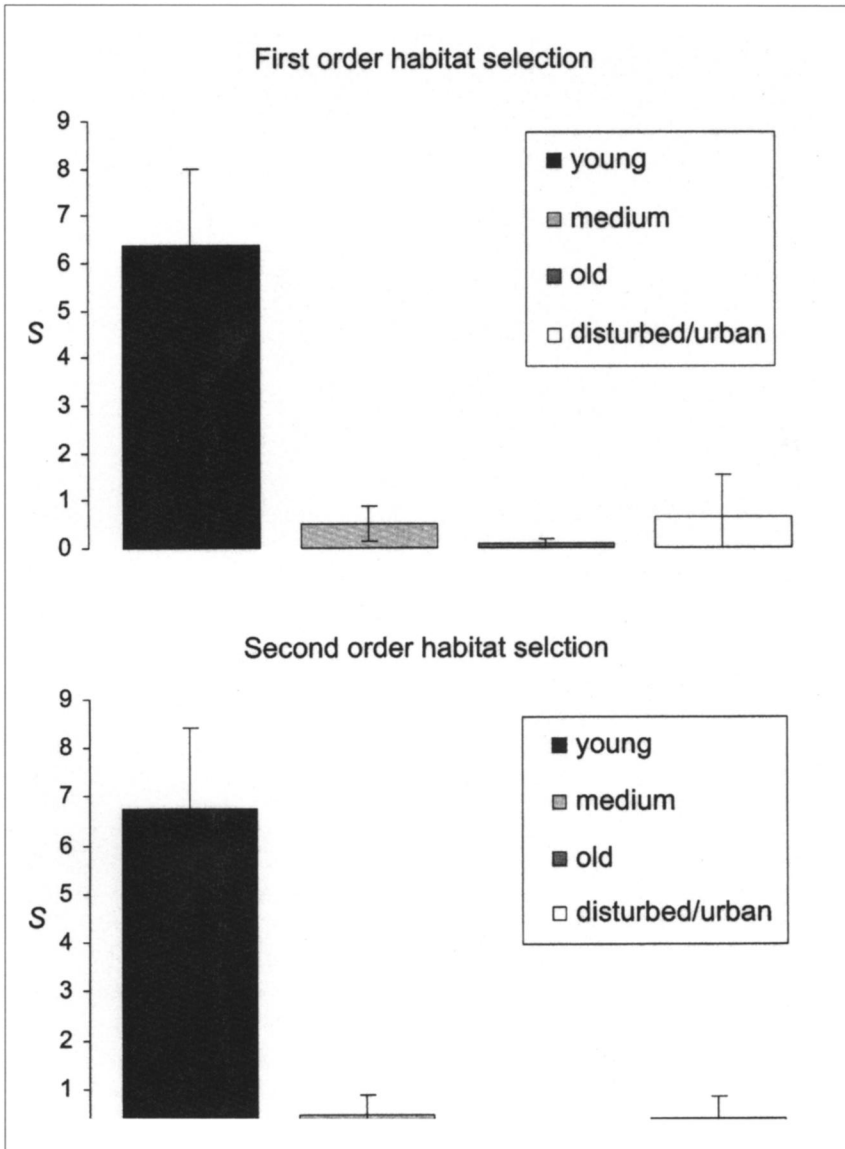


Figure 2. First and second order *N. f. smalli* habitat selection ratios (S) and SE bar for young, medium, old, and disturbed/urban hammock type on Key Largo, FL.



selection ratios of 6.3 and 6.7 for first and second order ratios, respectively (Fig. 2).

The ranges of 1 male and 1 female woodrat overlapped, 11% for the male and 27% for the female. Six female ranges overlapped an average of 49%, and 2 males overlapped an average of 8%. Woodrats that did not overlap ranges did not occupy areas adjacent to other woodrats or occupied adjacent areas during different time periods.

## Discussion

### Movements

Male Key Largo woodrats had larger average monthly ranges and larger ranges in both spring and summer than females. Ranges of female woodrats were smaller in the spring and summer than the fall. Larger ranges for *N. f. smalli* males compared to females was observed by Sasso and Gaines (2002), but not by Hersh (1981). Seasonal shifts in range sizes were likely due to the reproductive cycles of the woodrats. It is probable that males extended their ranges (relative to females) in search of mates when they were sexually active in the spring and summer. Conversely, females condensed their ranges for the care and suckling of young. Research on *N. f. samlli* (Hersh 1981, Sasso 1999) and other *N. floridana* spp. (Hamilton 1953, Haysmith 1995) have generally shown that eastern woodrat sexual activity peaks in the spring and summer.

Female Key Largo woodrats appeared socially tolerant of each other with ranges overlapping an average of 49%. On numerous occasions, we found 2 female woodrats (possibly related) out of their nests at night and in close proximity to each other. Still, we never found 2 adult woodrats sharing a nest during daytime hours. Males appeared to be intolerant of one another. Ranges of only 2 males overlapped an average of 8%. It may prove important for the captive breeding and reintroduction of *N. f. smalli* to insure that males are separated in captivity and given ample space when reintroduced. We would recommend that males be given separate enclosures for captive breeding and be placed at least 110 m apart (the approximate diameter of their spring and summer range, assuming ranges are circular). When male *Neotoma* sp. are not given adequate amounts of habitat with nesting sites, they can become highly territorial and aggressive (Kinsey 1977). The data suggests it might be feasible to introduce female Key Largo woodrats in closer proximity to each other than males; however, it is important to note that females have also been highly territorial and aggressive when resources were limited (Kinsey 1977).

Although we did not find County Road 905 to be a source of mortality, the road appears to create a barrier to woodrat movement. At the Key Largo woodrat's currently low densities, this problem may be minimal, but if the population rebounds, the road could be a cause for concern and may require management action.

### Habitat use

Our study suggests that Key Largo woodrats select for young hammock habitat. By eliminating the biases inherent in the use of trapping grids, we hoped to clarify some of the contradictions found in the literature pertaining to *N. f. smalli* habitat selection. One of the major assumptions of determining habitat selection via radio telemetry is that individual animals are free to select from all of the habitats available on the study site (Johnson 1980, White and Garrot 1990), not just those areas with traps. By radio-tracking woodrats, we assume that regardless of their place of capture, they are free to use the habitats that they preferred and avoid habitats they don't want to use (Johnson 1980, White and Garrot 1990). The woodrats in this study chose to utilize young hammock habitat (disturbed after 1971), although it made up less than 13% of the study area and was usually situated in small (>10 ha), isolated patches. The areas of young hammock utilized by the woodrats were described as having a more open canopy and a denser understory than other areas of the hammock forest (McCleery 2006). This study challenges the idea that Key Largo woodrats preferred old hammock (Barbour and Humphrey 1982, Brown 1978, Hersh 1978, and USFWS 1999). However, the research is congruous with research on other eastern woodrats in Florida and the Southeastern United States that showed higher trap success in ecotonal areas and areas of dense understory vegetation (Pearson 1952, Neal 1965, Haysmith 1995, Wilson 1999). The forests of north Key Largo have been managed for mature hammock forest, with little early succession hammock (< 50 ha) created over the last 20 years. Studies suggest this was probably not the habitat that *N. f. smalli* encountered prior to the Key Largo woodrats discovery, at which time its population appeared to be thriving (Small 1923). For approximately 250 years prior to their discovery, the forests of Key Largo had been altered for lumber and agriculture (Strong and Bancroft 1994). Prior to human alteration, the forests of Key Largo would have experienced the natural disturbance regimes of fire and wind, especially hurricanes (Ross et al. 1995), that would have created forest stands of varying ages. For these reasons, we believe the Key Largo woodrat population would benefit from the management of north Key Largo's hammock forest for a mosaic of forest ages (McCleery 2006), instead of simply as a climax forest. Additionally, our data suggests captive-raised woodrats should be released within or near early successional hammock.

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