AN EVALUATION OF HABITAT SELECTION AND AN ABUNDANCE ESTIMATE FOR THE ENDANGERED KEY LARGO WOODRAT

by

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(Under the direction of Michael T. Mengak and Steven B. Castleberry)

ABSTRACT

The Key Largo woodrat (KLWR; *Neotoma floridana smalli*) is an endangered species endemic to the island of Key Largo. Despite protection of its remaining habitat from development, the population continued to decline over the last 20 years. Information on KLWR habitat preferences required to effectively manage the population is lacking, as is a means to monitor abundance. The objectives of this study were to examine habitat selection by KLWR at two spatial scales, the macro and micro-scales, and identify an efficient sampling design that can be used to monitor this rare population. Results of habitat and nest site selection suggest KLWR is limited by the availability of quality nest habitat and would benefit from the addition of artificial nest substrate and the continued protection of the forested uplands of Key Largo. Stratified random sampling was the most effective design and can be used to monitor the status of KLWR.

INDEX WORDS: Key Largo woodrat, *Neotoma floridana smalli*, macrohabitat selection, microhabitat selection, nest site selection, logistic regression, resource selection function (RSF), adaptive cluster sampling, radiotelemetry, abundance, closed population model, occupancy.

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DEDICATION

To my mom for her love and support.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

SUMMARY

The Key Largo woodrat (KLWR, *Neotoma floridana smalli*) is a federally endangered subspecies of the eastern woodrat (*Neotoma floridana*) endemic to Key Largo, Florida. KLWR historically ranged throughout the upland forests (hardwood hammocks) of Key Largo but is now restricted to federal and state managed lands on the northern one-third of the island (Barbour and Humphrey 1982). Despite protection of its remaining habitat from development, KLWR continued to decline since its listing in 1984 (McCleery et al. 2006b). The cause of the population decline is unknown, but the quality of existing habitat appears severely compromised. Past disturbances to the hardwood hammocks, such as farming and abandoned development projects, altered the structure and composition of the forested landscape. The degraded forest habitat may be further compromised by fragmentation and proximity to heavily urbanized areas. Fragmentation increased the amount of forest edge, which assisted in the establishment of red imported fire ants (*Solenopsis invicta*; Forys et al. 2002). Fire ants are known to alter habitat use by small mammals (Smith et al. 1990, Killion and Grant 1993, Killion et al. 1995, Holtcamp et al. 1997) and may have reduced the quality of foraging habitat for KLWR. Urban areas offer year round food sources to predators, such as feral cats (*Felis catus*) and raccoons (*Procyon lotor*), potentially increasing their abundances (Hoffman and Gottschanng 1977, Prange et al. 2005) and KLWR predation levels.

Past KLWR studies focused on the differential use of forest patches at varying stages of recovery from disturbances, and were conducted at large spatial scales. Results were conflicting and shed little light on factors restricting KLWR (Hersh 1978, Barbour and Humphrey 1982, Keith and Gaines 2002, Sasso and Gaines 2002, McCleery et al. 2006b; Goodyear, unpublished report). In addition, little information is available on microhabitat selection by KLWR. Since animal populations are limited by factors that occur at multiple spatial scales, a multi-scale approach to observing habitat selection is often most informative (Hilden 1965, Johnson 1980). Given the uncertainty surrounding habitat requirements of KLWR and factors contributing to its decline, it is imperative that additional information on habitat selection be gathered to assess the quality of existing habitat and effectively guide recovery of the population

Nest sites are critical resources for KLWR, and are used as protective cover and refugia during inactive periods (McCleery et al. 2006b; Goodyear, unpublished report). Although KLWR are known to build and maintain stick nests (Goodyear, unpublished report), recent results suggest artificial nest substrate (i.e., rock and debris piles) is a preferred resource for nesting (McCleery et al. 2006b). In addition, recently disturbed areas characterized as young hammock were believed to be preferred nesting habitat (McCleery et al. 2006b). However, artificial substrate occurs frequently in recently disturbed areas, and may be confounded with young hammock. Distinguishing between young hammock and artificial nest substrate as preferred resources for nesting is critical since management recommendations differ greatly for each.

In addition to information on habitat selection, recovery of KLWR would benefit from a monitoring program to gauge the effectiveness of prescribed management. Monitoring the abundance of a rare species, like KLWR, is challenging using traditional sampling designs.

Equal probability designs, such as simple random sampling, often yield imprecise estimates even with large sample sizes. In addition to being rare, there is evidence KLWR may be clustered due to an association with artificial nest substrate (McCleery et al. 2006b). Adaptive cluster sampling (ACS) was developed as means to estimate the abundance of rare and clustered populations with greater precision (Thompson 1990). If successful, the increased efficiency of ACS would allow for a more cost-effective method to monitor KLWR and evaluate effectiveness of prescribed management.

The goals of this research were to examine a variety of factors potentially restricting KLWR, such as predator activity, structure and composition of vegetation, and availability of nest sites, by identifying macro and microhabitat selection. Nest site selection was evaluated to distinguish between the importance of artificial nest substrate and hammock age as nest habitat for KLWR. Collectively, results were used to recommend a management strategy to recover the population and reduce the risk of extinction. In addition, I compared the efficiency of adaptive cluster sampling to stratified random sampling in order to recommend an optimal design to monitor KLWR abundance and evaluate the effectiveness of recovery efforts.

LITERATURE REVIEW

KLWR Ecology and Habitat Use

The Key Largo woodrat (KLWR, *Neotoma floridana smalli*) is the southern-most sub-species of the eastern woodrat (*Neotoma floridana*) and is endemic to Key Largo, Florida. The insular population of KLWR is separated from its nearest conspecific by the southern one-third of the Florida peninsula (Hersh 1981). Although KLWR historically occurred throughout the upland forests of Key Largo, the remaining population is now restricted to the northern one-third of the island due to habitat loss (Barbour and Humphrey 1982). Previous attempts at evaluating population status varied in methodology, but collectively demonstrated a consistent decline over the last 25 years (McCleery et al. 2006b). The population decline occurred despite the protection of its remaining habitat from development and its listing as an endangered species. Recent population estimates and a viability analysis suggest KLWR is at a high risk of extinction within the next ten years (McCleery et al. 2005, McCleery et al. 2006b).

Past research on KLWR habitat selection focused on differential use of forest patches, characterized by age class, in an effort to assess habitat quality and guide recovery of the population (Hersh 1978, Barbour and Humphrey 1982, Keith and Gaines 2002, Sasso and Gaines 2002, McCleery et al. 2006b; Goodyear, unpublished report). Unnatural disturbances, such as farming and land clearing, coupled with excavation for commercial development, created a mosaic of forest conditions throughout the landscape, varying in seral stage (Ross et al., unpublished report). It was hypothesized that the effect of these disturbances, and resulting heterogeneity in patch age, negatively impacted the persistence of KLWR. However, results were conflicting. Early efforts determined KLWR used mature or climax forest more frequently and were negatively impacted by the overall reduction of mature forest (Hersh 1981, Barbour and Humphrey 1982). In a later study, a difference in densities of KLWR was noted between northern and southern portions of Key Largo and was attributed to a preference for mature forests and areas far removed from residential development (Humphrey 1988). However, additional studies found KLWR to use a variety of forest types and did not determine a preference for any particular age class (Keith and Gaines 2002, Sasso and Gaines 2002; Goodyear, unpublished report). More recently, KLWR was found to prefer newly disturbed patches of forest and was absent from mature forest (McCleery et al. 2006b). The discrepancy in results from past research creates uncertainty as to the relevance and predictive ability of using forest age class to identify habitat for KLWR. In order to better guide the recovery of KLWR and identify factors restricting the population, additional information on habitat selection extending beyond the use of different forest age classes is required.

Potential Restricting Factors

KLWR requires protective cover for suitable nest sites and quality foraging habitat within close proximity to the nest in order to minimize predation risk and optimally acquire resources (Orians and Pearson 1979). Due to their moderate size and terrestrial mode of life, *Neotoma* species are believed to be at a high risk to predation and rely heavily on nest sites and cover for protection (Rainey 1956). Changes in forest structure and composition could limit the quality of available nest sites and foraging habitat. Naturally occurring nest sites typically utilized by KLWR include the root systems of standing or wind-blown trees, logs, and solution holes (holes in the limestone substrate created by erosion; Goodyear, unpublished report). Recently, KLWR was found to use artificial substrate for nest sites, such as rock piles and debris from dumping activities, at a high frequency (McCleery et al. 2006b). Although it is common for *Neotoma* species to use anthropogenic structures for nesting, it is unclear if the observed pattern of nest use by KLWR was opportunistic or indicative of a decrease in the quality of naturally occurring nest substrate.

Housing developments, roads, and a waste transfer station, within and around the remaining hardwood hammock, resulted in fragmentation and an increase in anthropogenic food resources for raccoons (*Procyon lotor*) and feral cats (*Felis catus*), potentially increasing their densities (Hoffman and Gottschanng 1977, Prange et al. 2005). Feral cats are well documented predators of small mammals (Baker et al. 2005, Espinosa-Gayosso and Alvarez-Castaneda 2006) and raccoons have been shown to depredate small mammals, including Norway rats (*Rattus* *norvegicus*, Hoffman and Gottschanng 1977). Increased predation levels due to unnaturally high predator densities could be contributing to KLWR population declines. The increase in forest edge resulting from fragmentation has facilitated the establishment of red imported fire ants (*Solenopsis invicta*), which favor disturbed areas lacking canopy cover (Forys et al. 2002). Past studies found small mammals altered patterns of habitat use to avoid fire ants (Smith et al. 1990, Killion and Grant 1993, Killion et al. 1995, Holtcamp et al. 1997). High fire ant abundance may have lowered the quality of foraging habitat for KLWR.

Habitat Selection and the Importance of Scale

Selection is the process by which an animal chooses a resource or habitat (Johnson 1980). The use of a habitat is considered selective if the habitat is exploited disproportionately to its availability (Johnson 1980). Animals select habitats at several spatial scales, and factors influencing selection vary across scales (Hilden 1965, Johnson 1980, Litviatis et al. 1994). In order to gain meaningful insights into habitat selection criteria, careful consideration must be given to scales chosen and factors likely affecting selection at those scales (Manly et al. 2002).

Habitat selection is commonly viewed at 2 spatial scales, the macro and micro-scales (Litviatis et al. 1994). Macro-scale studies examine landscape level processes, which limit the distribution of a population. An examination of micro-habitat selection typically focuses on selection of resources, such as food and cover, required for an individual to survive and reproduce. Considering the multi-scale effects experienced by animals, examining habitat selection at both the micro and macro-scales may offer the greatest insight to animal-habitat relationships (Morris 1984, Snyder and Best 1988).

Previous KLWR studies focused on habitat selection at the macro-scale. An examination of micro-scale habitat selection, selection of resources within the individual foraging range, may provide valuable information on habitat preferences which are obscured at the macro-scale (Jorgensen and Demarais 1999, Castleberry et al. 2002). Sasso and Gaines (2006) evaluated KLWR microhabitat selection by comparing habitat around used and unused trap locations and suggested larger canopy trees and open understory were most important. However, traps may bias observed habitat selection due to imperfect detection and from luring animals into poor quality habitats. Radio-telemetry can be used to estimate habitat selection without the biases of trap response (Douglas 1989). McCleery et al. (2006a) used radio-telemetry to estimate selection of hammock age class by foraging individuals but measured availability at the scale of the study area and did not infer fine-scale selection. Microhabitat selection by KLWR has yet to be evaluated using radio-telemetry and could provide useful information on important habitat and resources.

Identifying habitat selection is critically dependent on accurate and biologically meaningful definitions of availability (Johnson 1980, McClean et al. 1998). Within areas defined as available to an individual, it is typically assumed that resources are equally available. The distribution of resources relative to the individual is not considered. For central place foragers, resources farther from the central place may be less available, as predation risk and energy expended increase with increasing distance from the central place (Orians and Pearson 1979). Due to increased predation risk at far distances, central-place foraging theory predicts individuals will be more selective of resources at greater distances from the central place (Schoener 1979). *Neotoma* species are nocturnal herbivores which exhibit central place foraging behavior (McGinley 1984). Woodrats typically maintain one or more nests that serve as daytime refugia and bases for nightly foraging bouts. Little information is available on KLWR foraging behavior, but individuals are known to maintain small home ranges,

and natural nest substrate. The abundance of artificial substrate (i.e., rock and debris piles) was the most important variable in predicting the occurrence of KLWR, followed by areas with larger overstory trees, of which the root systems are used as nest sites. In addition, KLWR selected areas with lower abundances of feral cats (*Felis catus*) and raccoons (*Procyon lotor*). The distribution of KLWR, therefore, appears restricted by a reduction in quality nesting habitat, which may be exacerbated by high mammalian predator abundance. Although a mammalian predator effect was supported by the data, manipulative studies are needed to better determine if predator reductions would effectively increase KLWR occupancy.

Observed nest use was consistent with macrohabitat selection results, where individuals mainly used the root systems of overstory trees and artificial substrate for nest sites. Artificial nest substrate was used more frequently, however, and KLWR was found to select nest sites based on the availability of artificial nest substrate. The high proportional use of artificial substrate suggests naturally occurring nest sites are in short supply, possibly due to past disturbances to the hammocks (i.e., farming and development). Due to the relatively short time since disturbance (70-80 years), current hammock conditions may not be fully representative of mature hammock, lacking trees large enough to provide adequate substrate for constructing natural nests. Additionally, artificial substrate likely offers greater protection from predators than natural substrate. Thus, high predator densities may be furthering the reliance on rock and debris piles for refugia. Although KLWR nested in younger hammock, the observed association appears to be confounded with the abundance of artificial substrate available in younger patches of hammock, as hammock age class alone was a poor predictor of nest site selection.

I found no evidence that KLWR selected foraging locations based on the structure or composition of vegetation. Consistent with central-place foraging theory (Schoener 1979), I found that KLWR forage more frequently closer to the nest. The limited range of movements, and lack of habitat selection within the home range, suggests individuals may not be restricted by food resources or microhabitat, and can readily obtain necessary resources without incurring high risks associated with long distance movements.

ACS was less efficient than stratified random sampling as a method to estimate total population size. Delineating three strata based on the density of artificial substrate and hammock age using poststratification, effectively lowered estimator variance and produced the most precise estimate of total population size. Despite the reduction in estimator variance, gaining meaningful estimates of total population size with the optimal sampling design will be costly. Given that habitat improvement is likely to be conducted at smaller spatial scales, monitoring total population size may be unnecessary. Conducting habitat improvement under the framework of adaptive management, where the effects of prescribed management at treatment sites are measured against control sites, would provide feedback on the effectiveness of management in recovering the population without the costs of monitoring total population size.

Based on my results, KLWR would likely benefit from the continued protection of the hardwood hammocks which would promote the maturation of the hammock, increasing the availability of large overstory trees used as nest sites. However, immediate habitat improvement may require the addition of artificial nest substrate while the forest recovers from past disturbances. Given the evidence of a potential negative effect of high predator densities, experimental predator reductions, coupled with the addition of artificial nest substrate, may be the most effective means of improving habitat quality, while allowing for greater insight into the roles of each factor on limiting the KLWR population. Monitoring the effects of habitat improvement at small spatial scales would likely be the most cost effective approach for evaluating the success of prescribed management.

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