STATUS OF THE SPECIES – Key Largo woodrat (*Neotoma floridana smalli*)

Legal status – Federal: *endangered*, 1984; State: *endangered.*

The Key Largo woodrat (KLWR) was first listed as a threatened species in 1969 under the Endangered Species Conservation Act of 1969. However, this listing only afforded the KLWR protection on U.S. Fish and Wildlife Service (Service) lands. The KLWR was listed as endangered under the Endangered Species Act of 1973, as amended (Act) (87 Stat. 884; 16 U.S.C. 1531 *et seq.*) on September 21, 1983, through an emergency listing action (Service 1983). The emergency listing was deemed necessary to provide full consideration of the welfare of this species during a section 7 consultation with the Rural Electrification Administration. The Rural Electrification Administration's action was a loan to the Florida Keys Electric Cooperative for construction of a project that would accelerate loss of KLWR habitat. The KLWR was proposed for listing as an endangered species with critical habitat on February 9, 1984 (Service 1984a) and was officially listed as endangered under the Act on August 31, 1984 (Service 1984b). The proposed critical habitat designation was withdrawn on February 18, 1986 (Service 1986).

Species description

Appearance/morphology

The color of the KLWR is described as sepia or grey-brown above shading into cinnamon on the sides, with cream or white ventral coloration. The forefeet are white to the wrist and the hindfeet are primarily white to the ankles. The KLWR has large ears, protuberant eyes, and a hairy tail. The head-and-body-length of the KLWR ranges from 120 to 230 millimeters (mm) (4.7 to 9.1 inches), and their tail length ranges from 130 to 190 mm (5.1 to 7.5 inches). Males, on average, weigh 258 grams, while the females tend to be much smaller, weighing only 210 grams (Hersh 1981).

Taxonomy

The KLWR is the southernmost subspecies of the eastern woodrat (*N. floridana*), a species widely distributed in the eastern United States (Sherman 1955; Schwartz and Odum 1957).

Life history

The KLWR is endemic to the hammocks of Key Largo (Service 2008). This herbivorous rodent, like other members of the genus *Neotoma*, builds large structures as nests and shelters. The structures are comprised of sticks, twigs, and various other objects and assembled into mounds that can reach 4 feet (1.2 meters) high and 6 to 7 feet (1.8 to 2.1 meters) in diameter. KLWRs frequently locate these structures adjacent to tree stumps, fallen trees, or boulders and may use old sheds, abandoned cars, rock piles, and machinery as shelter and nest sites. Structures generally consist of a central chamber and may have several entrances. Normally, only one adult woodrat inhabits a structure, and a single woodrat may build and use several structures over its

lifetime. Woodrats are also active climbers, and often climb along fallen trees to move across the forest floor (Service 1999).

Woodrats can reproduce year round, although, reproductive activity has been observed to be greatest during the summer. The KLWR usually gives birth to two young per litter, but litter size can range from one to four young. Female woodrats may produce two litters per year. Both sexes of the KLWR reach sexual maturity in about 5 months. Based on the known life spans of other subspecies of *N. floridana*, the life expectancy of the KLWR is likely 1 to 3 years (Service 1999).

Habitat

The KLWR is a resident of tropical hardwood hammocks, the climax vegetation of upland areas in the Florida Keys. Hammocks provide a shady, humid microclimate with less wind and temperature variation than more exposed habitats. The soils are poorly developed, typically consisting of shallow humus and litter overlying the limestone substrate, but may become deep in some forested areas. Tropical hardwood hammocks on Key Largo include a greater number of tropical plants than hammocks on the mainland. Most of these tropical species are West Indian shrubs and trees with a variety of vine species from temperate North America and the West Indies. Tropical hardwood hammock canopy ranges from 29.5 to 39.4 feet (9 to 12 meters) in height. Canopy trees include black ironwood (*Krugiodendron ferreum*), gumbo limbo (*Bursera simaruba*), Jamaican dogwood (*Piscidia piscipula*), mahogany (*Swietenia mahagani*), pigeon plum (*Cocoloba diversifolia*), poisonwood (*Metopium toxiferum*), strangler fig (*Ficus aurea*), and wild tamarind (*Lysoloma latisiliquum*). Tropical hardwood hammock understory contains torchwood (*Amyris elemifera*), milkbark (*Drypetes diversifolia*), wild coffee (*Psychotria undata*), marlberry (*Arisia escallonioides*), stoppers (*Eugenia* spp.), soldierwood (Colubrina elliptica), crabwood (*Gymnanthes lucida*), and velvetseed (*Guettarda scabra*). Ground cover contains yellowroot (*Morinda royoc*) and snowberry (*Chicocca parviflora*).

Vegetative composition and structure influence density and distribution of woodrats by affecting their ability to find food resources, nest materials, and secure cover. The two most important aspects of woodrat habitat are materials for building stick nests and ample cover (Rainey 1956). Stick nests are used for resting, feeding, and breeding, and ground cover provides travel and escape routes.

Distribution

Historically, the KLWR occurred throughout Key Largo south to near Tavernier, but the species' present range includes only the northern portion of Key Largo (Frank et al. 1997). About 2,498 acres (1010 hectares) of suitable KLWR habitat occur within this range, and a total of 2,188 acres (885 hectares) (88 percent) are currently protected for conservation purposes.

From the early 1950's to the present, the KLWR has lost much of its hammock habitat due to land clearing for commercial and residential development. Evidence suggests the population of the KLWR has decreased significantly over the last 20 to 30 years.

Population dynamics

Past studies to monitor the population size of the KLWR vary greatly with respect to methods and trapping effort. Therefore, these studies should not be considered as replicate samples of the KLWR population. However, since each monitoring study provides information on the relative abundance of the KLWR, the studies can be used collectively to roughly assess the population trends of the KLWR. Based on the monitoring data, it does appear that the size of the KLWR population may have declined from levels observed 20 to 30 years ago (McCleery et al. 2006; Winchester 2007), and may currently be precariously small. Frank et al. (1997) suggests the substantial decline in KLWR population occurred sometime in the late 1980s and early 1990s. The following discussion summarizes the information available from past monitoring efforts and studies of the KLWR.

In 1952, anecdotal evidence suggested the KLWR occurred on Key Largo, but was most abundant on the northern end of the island. As discussed above, the presence of KLWR nests and shelters can be used as an index of KLWR abundance in an area. A survey of a site in North Key Largo documented 40 stick nests within a site located adjacent to County Road (CR) 905 approximately 4 miles north of its intersection with U.S. Highway 1 (Service 2003).

In 1970, an effort was made to reestablish the KLWR within Lignumvitae Key Botanical State Park by relocating a total of 19 KLWRs (10 males and 9 females) from North Key Largo (Brown and Williams 1971). The introduction was apparently successful based on the stick nests observed in the area by Hersh (1978) and park rangers. Park rangers reported observing stick nests on Lignumvitae Key until about 1986.

Hersh (1978) studied the KLWR in North Key Largo during 1976 and 1977. Hersh (1978) reported a density of 0.9 individual per acre (0.36 per hectare), and reported stick nests were common and could be used as a general indicator of KLWR presence. Hersh (1978) developed an index of 5.6 stick nests per KLWR, and observed mature hammocks supported the highest densities of the KLWR.

In 1979, Barbour and Humphrey (1982) surveyed the KLWR in Key Largo and estimated there were 3,666 KLWR stick nests and 645 individual KLWRs within a 222-acre (89.8-hectare) study area. These estimates were based on live trapping using 40 strip transects established within habitat adjacent to CR 905. Barbour and Humphrey (1982) also found KLWRs on Lignumvitae Key at comparable densities to those on North Key Largo, and estimated 85 KLWRs occurred on the island at a density of 0.9 per acre (0.36 per hectare). Barbour and Humphrey (1982) concluded KLWR density was highest in mature forests, and active stick nests were strong indicators of healthy KLWR populations.

In May and June of 1985, Goodyear (1985) conducted live trapping for the KLWR at 15 sites within hammock habitat in North Key Largo. A total of 59 individual KLWRs were captured during the survey. Goodyear (1985) observed the KLWR was found in areas with and without stick nests. Goodyear (1985) also concluded the following: (1) KLWR are not dependent on stick nests as shelters; (2) stick nest construction is based on habitat conditions, and habitats with abundant natural cover were observed to contain fewer stick nests; (3) disturbance could benefit KLWR in habitats with few natural cavities such as recently cleared early successional sites; and (4) older hammocks with increased structural complexity appear to be optimal habitat.

From March through May in 1986, Humphrey (1988) surveyed six sites in Key Largo for the KLWR. A total of 129 individual KLWRs were captured during the study. Humphrey (1988) reported a mean density of 1.3 KLWR per acre (0.53 per hectare) for sites in the north end of Key Largo, and a higher density of 4.9 KLWR per acre for sites farther south, but still in north Key Largo. Humphrey's (1988) KLWR densities were 7 times greater than densities reported by Hersh (1978). Humphrey (1988) also concluded that stick nests were poor estimators of KLWR density and tended to underestimate density. Extrapolating average density over acres of habitat available, Humphrey (1988) estimated a population of 6,500 KLWRs in North Key Largo.

Frank et al. (1997) conducted a live trapping survey of the KLWR within North Key Largo during January through May of 1995. Live traps were places within 48 transects [each 820 feet (250 meters) in length), and four 165-meter by 165-meter (541 feet by 541 feet) trapping grids. Frank et al. (1997) found densities of the KLWR had declined significantly from those reported by Humphrey (1988). A total of only 42 individual KLWRs were captured during the study. Moreover, stick nests were virtually absent from the areas surveyed. Frank et al. (1997) expressed concern that low densities coupled with the absence of stick nests could indicate significant declines in the KLWR population, and suggested that intensive monitoring and management be initiated by State and Federal land managers. Since 1997, the KLWR has been absent on Lignumvitae Key as evidenced by both trapping and lack of sign (Greene 2007).

Sasso (1999) monitored the KLWR from July 1996 through April 1998, using the same trapping locations and methods used by Frank et al. (1997). Sasso (1999) observed KLWR densities and stick nest numbers similar to those reported by Frank et al. (1997). Sasso (1999) concluded intermediate-aged hammock may provide better habitat conditions for the species than old, mature hammock, and suggested a possible role for natural disturbance (*e.g.,* hurricanes) in maintaining optimal KLWR habitat.

From 1998 to the present, monitoring of the KLWR has been conducted at the CLNWR by CLNWR staff and others, using live traps arranged in both grids and transects. In April 2002, the Service estimated a population size for the KLWR of 200 individuals (Service 2003).

Trapping initiated in January 2002 by McCleery (2003) documented low numbers of KLWRs and a high mortality rate of radio-collared individuals. McCleery (2003) trapped 60 randomly-established plots on North Key Largo, and captured 10 individual KLWRs, a capture success rate of 17 percent. In October 2002, McCleery estimated a population size for the KLWR of less than 90 individuals (Service 2003).

In 2005, Winchester (2007) conducted live trapping for the KLWR within the CLNWR and the Dagny Johnson State Botanical Park. Winchester (2007) captured a total of seven KLWRs on 7 of 40 randomly placed grids, a capture rate of 18 percent.

Potts (2008) also conducted live trapping for the KLWR in North Key Largo. A total of 16 individual KLWR were captured at 137 trapping stations within the CLNWR. Potts (2008) also captured 42 individual KLWR from 152 artificial nest structures located throughout the CLNWR. In addition, Potts (2008) caught 31 KLWR at the Nike Missile site within the CLNWR, and 13 KLWRs at the Dagny Johnson State Botanical Park. A total of 102 individual KLWRs were captured during Potts 2008 survey effort. Based on her survey work, Potts (2008) estimated the KLWR population in North Key Largo to be about 300 animals.

In 2009, Potts (2009) conducted live trapping for the KLWR in North Key Largo. A total of six individual KLWRs were captured at 136 trapping stations established within the CLNWR and Dagny Johnson State Botanical Park. Potts (2009) also captured 42 individual KLWRs from 157 artificial nest structures located throughout the CLNWR. In addition, Potts caught 15 individual KLWRs at the “car dump” and “Harrison Tract” sites within the CLNWR, and 5 individual KLWRs at the “Ocean Forest” and “Power Pole 212” sites within the Dagny Johnson State Botanical Park. A total of 68 individual KLWR were captured during Potts 2009 survey effort. Potts (2009) noted a substantial drop in detectability of male KLWRs during her 2009 survey effort and could not estimate the KLWR population size.

In 2010, Potts conducted additional live trapping for the KLWR in North Key Largo. A total of two individual KLWRs were captured at 136 trapping stations established within the CLNWR and Dagny Johnson State Botanical Park. Potts (2010) also captured 6 individual KLWRs from artificial nest structures located and 13 individuals during opportunistic sampling throughout the CLNWR. A total of 21 individual KLWRs were captured during Potts' 2010 survey effort.

Based on the most recent survey information (Potts 2008; 2009), the current small population size of the KLWR makes the possibility of extinction of this species more likely.

Critical habitat

Critical habitat is not currently designated for this species. When the species was proposed for listing in 1984, critical habitat was also proposed. However, the proposed critical habitat was withdrawn on February 18, 1986 (Service 1986; 1999).

Threats

Present or threatened destruction, modification or curtailment of its habitat or range

Habitat loss and degradation have adversely affected the KLWR. Significant commercial and residential development in the Florida Keys during the 1960s and 1970s has reduced the extent of habitat available to the KLWR, and degraded the condition of remaining habitat. However, the Federal government and State of Florida have protected the majority of the remaining high quality hammock available for KLWRs on North Key Largo through acquisition and management. A total of about 65 million dollars has been spent to acquire 2,147 acres (868.8 hectares) of habitat on North Key Largo. Moreover, the threat of loss and degradation of remaining KLWR habitat has been significantly diminished with the establishment of the Monroe County's *Rate of Growth Ordinance* (ROGO) in the 1990s. Due to these efforts, the threat of significant loss of remaining KLWR habitat is low.

Disease or predation

Parasites represent another potential threat to the KLWR because they are known to transmit viruses, bacteria, and protozoa that result in disease and mortality. These pathogens may also be carried by other species of mammals and ultimately transmitted to the KLWR. For example, the roundworm (*Baylisascaris procyonis*), carried by the raccoon (*Procyon lotor*), is known to transmit pathogens to Allegheny woodrats *(N. magister*) (LoGiudice 2001). Raccoons are abundant on North Key Largo. However, to date this species of roundworm has not been detected in raccoons occurring in this area.

Nonnative and invasive species

The presence of exotic animal species on Key Largo also may represent a threat to the KLWR. Feral and free-roaming domestic cats are known to occur within the CLNWR and the Key Largo Hammocks State Botanical Site. Densities of domestic cats appear to be greater near the residential areas of North Key Largo such as the Ocean Reef, Garden Cove, and the Ocean Shores developments. Cats are known to prey upon a variety of wildlife species, and studies indicate that small mammals often compose a large proportion of the diet (Churcher and Lawton 1989). As indicated above, cats are implicated in the death of introduced KLWRs. Moreover, domestic cats may hunt even when fed daily by humans (Liberg 1985). In addition to direct mortality, predators may also have indirect effects on prey species, such as KLWR. The risk of predation may alter the behavior of prey species resulting in reduced growth rates and reproductive output (Arthur et al. 2004). Consequently, it is likely feral and free-roaming domestic cats are affecting the KLWR population, but in the absence of specific studies their effects are difficult to quantify. The Service is attempting to address cats on North Key Largo and contracted the U.S. Department of Agriculture's Wildlife Services in 2005 to remove the

cats from the CLNWR. However, because humans continue to release cats in this area, ongoing efforts to remove cats will be necessary.

Other non-native species occurring on Key Largo that may pose a threat to the KLWR include the fire ant (*Solenopsis invicta*), the Burmese python (*Python bivittatus*), and the black rat (*Rattus rattus*) (Service 2008). The role of fire ants in the ecology of the North Key Largo hammocks is not specifically known, but predation by fire ants has substantially affected wildlife populations in other areas (Killion and Grant 1993). Because the KLWR is a ground nester, it may be vulnerable to predation by fire ants. With respect to Burmese pythons, the Service has funded a project currently being conducted by the U.S. Geological Survey (USGS) to detect and control Burmese pythons on Key Largo using visual surveys and experimental traps (Service 2008). Seven Burmese pythons have been captured in Key Largo since April 2007, and predation of KLWR by Burmese pythons was documented in 2007 (Snow 2008). Finally, black rats have also been established on Key Largo, and competition from this species may adversely affect the KLWR. The full extent of the threat from these exotic species is not yet known.

Climate change and sea level rise

Information for the United States at national and regional levels is summarized in the National Climate Assessment (Melillo et al. 2014). Because observed and projected changes in climate at regional and local levels vary from global average conditions, rather than using global scale projections, we use "downscaled" projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species and the conditions influencing it. In our analysis, the Service used our expert judgment to weigh the best scientific and commercial data available in our consideration of relevant aspects of climate change and related effects (*i.e.*, changes in air temperature, rainfall, storms, and sea level).

Current models predict changes in mean global temperature in the range of 4 degrees Fahrenheit (F) to 8 degrees F by 2100. How this manifests at the regional and local scale is uncertain, but model estimates for Monroe County are approximately 4.1 degrees F (National Climate Change Viewer (NCCV; USGS). A change of just a couple degrees can have profound effects, particularly at temperature extremes. For example, in Florida, winter frost, a 2-degree transition from 33^{o}F to 31^{o}F, greatly affects vegetation. While predicted changes in average annual temperature appear small, local and seasonal temperature variation may be greater, and an increase in the temperature of the global atmosphere may manifest as an increase or a decrease in local means and extremes. These temperature changes may alter KLWR activity patterns, reproductive behaviors and other life cycle activities that may be triggered by temperature. Food and nest site availability may be increased or reduced due to changes in soil moisture.

Ecosystems in Florida are sensitive to variation in rainfall. Despite a high average rainfall, much of Florida experiences seasonal drought that profoundly affects fish and wildlife resources. Florida's rain depends on both global and regional climate factors (*e.g.*, jet stream, El Niño, frontal progression, storms and hurricanes) and local weather (*e.g.*, thunderstorms, sea breezes, lake effects and local circulation) that are likely affected by climate change. Changes in rainfall intensity, distribution, and amount are possible. Monroe County may see changes of 0.4 inches per day (NCCV; USGS). Rainfall changes would influence the vegetative community within the project area and like temperature, would change soil moisture levels, possibly increasing or reducing burrow site availability.

Another predicted effect of climate change is to increase the frequency and intensity of severe storms, particularly tropical cyclones (hurricanes). Higher sea temperatures and high atmosphere conditions generate energy and conditions suitable for storms. Hurricanes may directly cause wildlife mortality, and have significant secondary effects, reshaping coastal habitat structure (barrier islands, beaches, salt/freshwater intrusion to marshes, and estuaries), replenishing water bodies and aquifers and renewing plant succession, which are not completely negative for wildlife. Hurricane effects will interact with rainfall and sea level changes, possibly exacerbating coastal flooding and severe erosion of these systems. Overwashes, blowouts, and water table changes may be common in the Keys. Hurricanes and other storms can result in the direct loss of KLWR, either by washing individuals out to sea or by wave action and inundation or "drowning".

Sea level rise (SLR) also impacts coastal erosion, changes tidal flows, results in more frequent flooding from higher storm surges, the fragmentation of islands, and the landward migration of shorelines (Melillo et al. 2014). Prior to these effects, habitat loss due to hydrology and vegetative community changes is likely to occur. Modeling tools are available that provide location-specific information related to SLR in Florida. These spatial models estimate areas of inundation under various climate change scenarios. Regardless of scenario, these tools identify relatively vulnerable areas on the landscape.

For the KLWR, increased soil moisture and vegetative community changes are of particular concern. Hammocks characteristic of the upper Florida Keys will ultimately be replaced by mangrove communities (Sternberg et al. 2007; Su Yean Teh et al. 2008). Worst-case models forecast an 88 percent loss in hammock vegetation within Key Largo by 2100 (Bergh 2009). Consequently, survival of the KLWR will likely require resource management intervention or translocation to suitable habitat outside of North Key Largo.

Overall, climatic changes in south Florida could also exacerbate current land management challenges involving habitat fragmentation, urbanization, invasive species, disease, parasites, and water management (Pearlstine 2008). It is difficult to estimate, with any degree of precision, which species will be affected by climate change or exactly how they will be affected. The Service will use Strategic Habitat Conservation planning, an adaptive science-

driven process that begins with explicit trust resource population objectives, as the framework for adjusting our management strategies in response to climate change (Service 2006).

Ongoing conservation efforts

Historically, the management of KLWR habitat on North Key Largo was limited to the maintenance of mature hammock vegetation. However, more recent management efforts have included the installation of artificial cover and nesting structures. For example, the Service enhanced KLWR habitat at the abandoned Nike Missile site within the Crocodile Lake National Wildlife Refuge (CLNWR) in 2004. Concrete buildings at the site were demolished, and piles of rubble and large rocks were constructed to provide cover and nest sites for the KLWR. In 2005, refuge volunteers began experimenting with the placement of artificial structures (comprised of rocks, sticks, artificial materials, etc.) to provide additional nesting sites and shelter for the KLWR within the CLNWR. About 38 percent of these structures were being used by woodrats (Simons et al. 2014). As of summer 2015, 850 artificial nesting and shelter structures have been installed within the CLNWR (Dixon 2015).

Due to the threat of extinction of the KLWR, and our lack of understanding on the specific mechanisms of the observed population decline in the KLWR, the Service began a captive propagation project for the KLWR in April 2002 to augment the wild KLWR population (Service 2003). The first captive raised KLWRs from the program were introduced into the wild in February 2010. Thirteen radio-collared, captive-bred KLWR were released at CLNWR in 2010, as part of a pilot reintroduction project. Of the 13 animals, 7 were found predated within weeks of their release, and another 3 were predated within 60 days of their release.

Feral cats (*Felis catus*) were not thought to be an issue at the release site, due to past trapping efforts and a lack of recent sightings. However, KLWR remains found in the area were consistent with cat predations. Since the first predation in February 2010, live traps were deployed at the release site by Service employees, volunteers, and contractors associated with the project. Approximately 30 cats were captured from the area before we attempted a second release in 2011, but predation was again the primary issue and more feral cats were captured from the area.

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