Eastern Woodrat Recovery Plan

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Printed by authority of the State of Illinois
April 2003

CONTENTS

EXECUTIVE SUMMARY

Eastern woodrats (*Neotoma floridana*) occur throughout much of the southeastern and south-central United States. Illinois occurs at the extreme northern periphery of *N. f. illinoensis*' range. As recently as the early 1900s, woodrats were found at numerous sites in Jackson, Union, Johnson, Pope, Gallatin, Alexander, and Hardin counties. Studies conducted during the 1990s documented the woodrat's presence at only 5 sites in Jackson and Union counties; these small, isolated populations had experienced significant inbreeding and loss of genetic variation.

Recovery of the eastern woodrat, currently classified as a state endangered species, is consistent with Objective 1.1.2.3 of the Department's Strategic Plan (Illinois Department of Natural Resources 2002) and it's legislatively mandated responsibility to "take all measures necessary for the conservation, distribution, introduction and restoration of birds and mammals" (520 Illinois Compiled Statutes 5/1.10). This plan advocates an overall goal of insuring the long-term viability of the eastern woodrat in Illinois by increasing genetic heterogeneity of extant populations, establishing populations at sites where woodrats occurred historically, monitoring population levels, and managing key habitats. Specific objectives and tasks proposed by the plan include:

Objective 1: Reclassify the eastern woodrat from state endangered to state threatened.

Objective 1 is met when a stable or increasing metapopulation of ≥50 individuals (fall estimate) has been established in an unoccupied part of the woodrat's historical range on the eastern part of the Shawnee Hills Natural Division (i.e., Johnson, Saline, Gallatin, Pope, or Hardin counties) and persisted ≥4 years after translocations have ceased.

Task 1.	Evaluate accessible sites where Nawrot and Klimstra (1976) found evidence of historical habitation by woodrats.
Task 2.	Identify additional sites with suitable habitat.
Task 3.	Classify sites according to their quality and spatial arrangement.
Task 4.	Seek public input.
Task 5.	Translocate woodrats to suitable but unoccupied habitats; identify successful, efficient protocols for releases.

Objective 2: Increase genetic heterogeneity of the Pine Hills metapopulation.

Objective 2 is met when woodrats are translocated successfully to Pine Hills from out-of-state sources or, if funding allows, studies document increases in indices of heterozygosity.

Task 6.	Release 10-15 woodrats per year for 2-3 years at Pine Hills.

Objective 3: Delist the eastern woodrat from state threatened status.

Objective 3 is met when (1) genetic heterogeneity of the Pine Hills metapopulation has increased, (2) a stable or increasing metapopulation has been documented at Pine Hills and associated sites for ≥4 consecutive years, (3) a stable or increasing metapopulation consisting of ≥50 individuals (fall estimate) has persisted on the eastern side of the Shawnee Hills Natural Division for ≥4 years after translocations have ceased, and (4) $\geq$2 additional populations consisting of $\geq$30 individuals each have persisted $\geq$2 years after translocations have ceased.

Task 7. Release wild woodrats at >2 unoccupied sites that occur in likely corridors between the Pine Hills and Shawnee Hills.

Objective 4: Implement a long-term monitoring program.

Objective 4 is met when the Department of Natural Resources implements a long-term monitoring program capable of detecting significant changes in the woodrat’s status.

Task 8. Identify efficient protocols for monitoring abundance.
Task 9. Train staff likely to participate in long-term monitoring efforts.
Task 10. Conduct surveys to monitor changes in the status of woodrats.

Objective 5: Evaluate and, where possible, implement appropriate habitat management practices.

Objective 5 is met when habitat management practices consistent with the woodrat’s ecology and recovery are implemented as part of the Land and Resource Management Plan for the Shawnee National Forest (USDA-Forest Service; 1992 amended plan or later revisions).

Task 11. Evaluate responses of woodrats to selected silvicultural practices.
Task 12. Participate in planning activities that guide habitat management practices on the Shawnee National Forest.

BACKGROUND

by Robert D. Bluett and Jack R. Nawrot

Species description

Like other eastern woodrats, *Neotoma floridana illinoensis* is characterized by large, rounded and sparsely haired ears, large black eyes, soft pelage and a tail covered by short hairs (Rainey 1956). Backs and sides of adults are grayish-brown to cinnamon tinged with black in varying intensities; the face is noticeably grayer, especially in older animals (Howell 1910, Layne 1955, Rainey 1956). Subadults are gray on the entire upper surface (Layne 1955). All age classes have white or buff underparts (Hoffmeister 1989, Crim 1961). Brownish stains caused by secretions from sebaceous glands are usually apparent along the mid-ventral line of males when sexually active (Nawrot 1974). Females possess 2 pairs of inguinal mammae (Hoffmeister 1989).

Howell (1910) reported average measurements for 8 adults collected from Wolf Lake, Illinois: total length 430mm (range 390-435); tail 195mm (187-205); hind foot 38mm (36-40). Measurements reported by Crim (1961) were similar to those noted by Nawrot (1974) (Table 1). Nawrot (1974) reported an average weight of 295g (255-370) for adult (>1 yr) males and 278g (260-320) for adult females. Adults <1 year of age weighed 200-245g when captured during the fall, with an average of 240g for males and 215g for females (Nawrot 1974). Subadults weighed 170-200g when captured during October through December (Nawrot 1974). Hoffmeister (1989) noted a dental formula of 1/1, 0/0, 0/0, 3/3. Baker and Moscarello (1969) described the karyotype of *Neotoma* as 2N = 52; FN = 56; autosomal pairs are 1 large biarmed, 2 small biarmed and the remainder acrocentrics.

Table 1. External measurements of eastern woodrats captured in southern Illinois (Nawrot 1974).

	Mean length (mm) with range in parentheses			
Sample	Total	Tail	Hind foot	Ear
15 adult males	342 (315-362)	170 (154-182)	35 (31-38)	24 (20-26)
15 adult females	341 (303-367)	169 (148-185)	35 (34-37)	24 (21-26)
7 subadults (6 male; 1 female)	310 (243-346)	158 (143-172)	33 (31-36)	21 (19-23)

Taxonomy

Woodrats were first noted in North America by Peter Kalm in 1749 in the Blue Mountains of Pennsylvania (Murphy 1952). In 1818, Ord assigned a woodrat taken in Florida to the Old World family of rats and mice and designated it *Mus floridanus*. Thomas Say rediscovered the woodrat along the Mississippi River below St. Louis in 1819; in 1825 he and Ord designated the new genus *Neotoma* (Burroughs 1961). *N. f. illinoensis* was first recorded in Illinois by Howell (1910:28-29), who stated: "*The animals are common at Wolf Lake, inhabiting the high rocky* *bluffs which border the east side of the lake. They live in crevices and caves into which they carry large quantities of sticks, leaves and other rubbish*."

Opinions regarding the subspecific taxonomy of *N. floridana* have varied over the years (Schwartz and Odum 1957, Hall and Kelson 1959, Hayes and Harrison 1992). Hall and Kelson's (1959) range map for 10 subspecies of *N. floridana* showed *N. f. illinoensis* occurring in the western half of southern Illinois and *N. f. magister* occurring in the eastern half of southern Illinois. Subsequent editions of this reference (Hall 1981) appeared to delineate the Wabash River as range limits for these subspecies. Schwartz and Odum (1957) also showed *N. f. illinoensis* occurring across southern Illinois and *N. f. magister* farther to the east. Nawrot (1974:59) agreed with this range delineation for the following reasons: "(1) The designation of a sub-species implies inherent geographic variation in morphology (Hall 1943, Lidicker 1962) and distinguishable morphological differences would not be expected to occur among woodrat populations occupying the Shawnee Hills; (2) Specimens of *N. f. magister* have never been collected in southeastern Illinois. The closest recorded occurrences of *N. f. magister* were in Harrison County, Indiana and Humphreys County, Tennessee (Schwartz and Odum 1957); and (3) Woodrat populations which once occupied the Shawnee Hills logically would have dispersed from the area of greatest population density and optimum habitat conditions located in Pine Hills, 65 miles west of the easternmost extent of the past range of *N. floridana* in southern Illinois."

N. f. magister is now considered a distinct species, *N. magister*, based on genetic (Hayes and Harrison 1992, Edwards and Bradley 2001) and morphological (Hayes and Richmond 1993) features which distinguish it from *N. floridana*. The historic range of *N. magister*, associated closely with the Appalachian Mountains, is thought to occur north of the Tennessee River to southern Indiana and southern Ohio northward to southeastern New York (Johnson et al. 1997).

Distribution and status

Eastern woodrats occur across much of the southeastern and south-central United States (Hall 1981). The subspecies *N. f. illinoensis* occurs in extreme southern Illinois, southeastern Missouri, western Kentucky and Tennessee, eastern Arkansas, most of Mississippi and Alabama, and the panhandle of Florida (Schwartz and Odum 1957, Hall 1981). Sites occupied by woodrats in southern Illinois are isolated from the nearest known populations 120.7 km (75 mi) to the west in Missouri and 136.8 km (85 mi) to the south in Tennessee (Nawrot and Spitzkeit 1986). *N. f. illinoensis* is classified as a state endangered species in Illinois, a species of concern in South Carolina, and a species in need of management in Tennessee; elsewhere its status is unknown or considered secure (Monty and Feldhamer 2002, Britzke 1998).

Skeletal remains establish a prehistoric (c.a. 8500-1500 BC) distribution in Illinois which included portions of Randolph and Monroe counties (Parmalee 1959, Parmalee et al. 1961), approximately 104.6 km (65 mi) north of where woodrats now exist in the state. Nawrot and Klimstra (1976) found direct evidence of past habitation by woodrats (e.g., skeletal remains, scats, houses) at 24 sites in Jackson, Union, Johnson, Pope, Gallatin, and Hardin counties, Illinois; they also documented extant populations at Pine Hills and Fountain Bluff (Fig. 1).

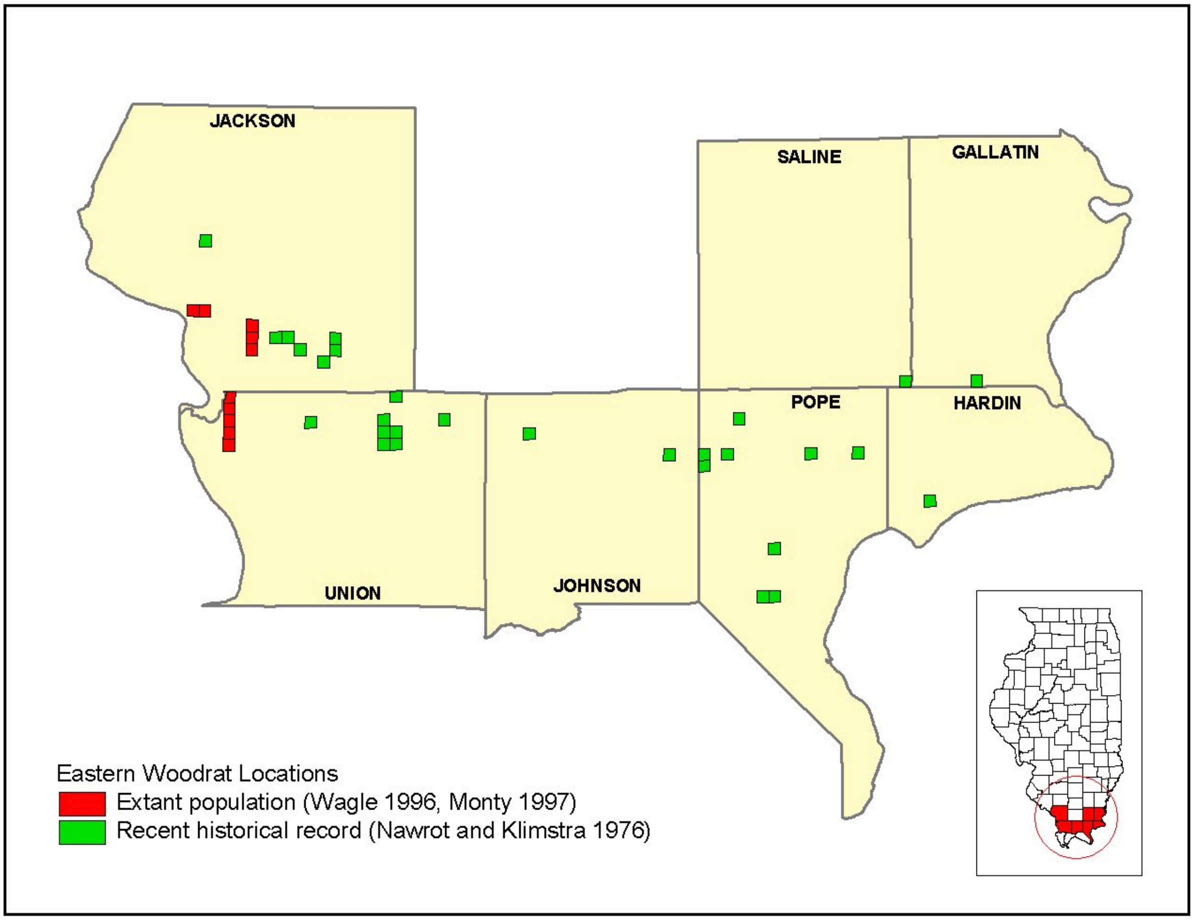

Figure 1. Distribution of the eastern woodrat (*Neotoma floridana illinoensis*) in Illinois.

Historical records for Illinois also include Chalk Bluff (Layne 1958) in Jackson County, Burden Falls in Pope County (Layne 1958), north of Rosiclare in Hardin County, and Horseshoe Lake in Alexander County (Wetzel 1947). Swayne (1949) reported a specimen from southern Jackson County. Specimens archived at the Illinois Natural History Survey include 17 collected from Union County during 1940 through 1960 and 1 collected from Alexander County in 1957 (Joyce Hofmann, Illinois Natural History Survey, personal communication). Nawrot (1974) listed 40 sites in Jackson, Union, Williamson, Johnson, Saline, Pope, Gallatin, and Hardin counties that seemed to offer suitable habitat but provided no direct evidence of past habitation; he speculated that woodrats had probably occurred at these sites but artifacts were destroyed by weathering and disturbance.

In Illinois, the largest and most persistent population of woodrats occurs at Pine Hills (Swayne 1949, Layne 1958, Crim 1961, Nawrot 1974, West 1986, Wagle 1996, Monty 1997). Fountain Bluff and Horseshoe Bluff are also important sites but populations tend to be smaller and more ephemeral than at Pine Hills (Crim 1961, Nawrot 1974, Wagle 1996). During 1959-60, Crim (1961) located about 207 active woodrat houses at Pine Hills, 21 at Fountain Bluff, and 5 at Horseshoe Bluff. During 1971-73, Nawrot and Klimstra (1976) found about 62 active houses at Pine Hills, 5 at Fountain Bluff, and none at Horseshoe Bluff. Nawrot and Spitzkeit (1986) reported that the Pine Hills population appeared to have declined from >150 individuals in 1959-

60 to 50-75 in 1973-74. As few as 15-30 individuals were thought to occur in 1985 (West 1986). However, a survey conducted in 1986 yielded an estimate of 50-75 individuals (Nawrot and Spitzkeit 1986).

Monty (1997) captured 283 woodrats at Pine Hills from 1993 through 1996; she estimated a minimum population of 101 individuals in 1994 and 60 during 1995 and 1996. Wagle (1996) captured 94 woodrats at Fountain Bluff from 1994 through 1995; the minimum number known alive each month varied from 8-30 individuals. Captures at Cripps Bend (n = 4), Horseshoe Bluff (n = 19) and Little Grand Canyon (n = 15) documented a more widespread distribution than thought previously (Monty et al. 1995, Wagle 1996, Monty 1997).

Possible reasons for reduced abundance of woodrats in Illinois and elsewhere

Nawrot and Klimstra (1976) speculated unusually harsh winters during 1912 and 1918 caused a large decline in numbers of woodrats at Pine Hills and extirpation of colonies in the Shawnee Hills where sites were isolated by man-made barriers to dispersal and weathered sandstone bluffs and outcrops provided relatively few secure locations for nests. Similarly, Fitch and Rainey (1956) noted reduced abundance of woodrats when extremely cold temperatures accompanied deep snowfall and ice.

Recent decreases in the distribution and abundance of *N. magister* along the northern and western peripheries of its range are well documented (Hayes 1990). *N. magister* is considered extirpated in Connecticut and New York and state endangered in Indiana, Maryland, New Jersey, and Ohio (Monty and Feldhamer 2002). Speculation about reasons for the widespread decline of *N. magister* is unsupported by direct evidence. Some hypotheses include: (1) fatal exposure as a secondary host to the raccoon roundworm, *Baylisascaris procyonis*, (2) loss of hard mast from chestnut blight (*Cryphonectria parasitica*), oak decline, gypsy moths (*Lymantria dispar*) and changes in succession that favor shade-tolerant species, (3) increases in abundance of avian and mammalian predators and (4) habitat fragmentation and associated factors (Poole 1940, Beans 1992, Balcom and Yahner 1996, Wright and Kirkland 1999). Destruction of habitat by residential development and Hurricane Andrew caused populations of the Key Largo woodrat (*N. f. smalli*) to decline enough to warrant its status as a federally endangered species (Monty and Feldhamer 2002).

Life history

Habitat

At the range-wide scale, *N. floridana* is a habitat generalist; it occurs in lowland hardwood forests (Neal 1967), coastal plains (Cross 1955), swamps (Hamilton 1953), and grasslands (Wiley 1971). At the local scale, its needs are more specific. Nearly all Illinois records are associated with limestone bluffs of the Mississippi River and sandstone outcrops in the Shawnee Hills (Nawrot and Klimstra 1976). The most limiting resource appears to be shelter such as vertical and horizontal fissures, caves or cave-like depressions, and piles of boulders at the base of rock formations (Crim 1961). Woodrats occasionally construct nests in abandoned buildings and at the base of trees near rock formations (Crim 1961).

Located in the southern section of the Ozark Division (Schwegman 1973), Pine Hills is characterized by a north-south oriented expanse of Devonian age Bailey limestone bluffs that rise abruptly from the Mississippi River bottoms (Weller and Ekblaw 1940). This feature stretches nearly 5 km (8 mi) from the northwest quarter of Section 3, T12S R3W in Union County to the southwest quarter of Section 27, T10S R3W in Jackson County (Nawrot 1974); smooth vertical faces or rough broken walls attain a height of 48.8 m (160 ft) in some places and average 24.4 m (80 ft) in height (Bassett 1925, Weller and Ekblaw 1940). LaRue Swamp borders the northern bluffs while Otter Pond and Wolf Lake, remnants of an old channel of the Big Muddy River, border the southern end (Mohlenbrock 1959).

Fountain Bluff rises 61 m (200 ft) above the Mississippi River as an isolated erosional remnant that is approximately 4.8 km (3.5 mi) long and nearly 2.4 km (1.5 mi) wide (Voigt and Mohlenbrock 1964). The west face of the bluff, which is bordered by the Mississippi River along most of its base, is essentially smooth with some tumbled boulders at the base; the east side, which has only occasional outcrops and a much more gradual slope, is bordered by State Highway 3 and intensively cultivated floodplains (Nawrot 1974). Horseshoe Bluff lies directly east of the Big Muddy River and is composed of relatively unresistant upper Mississippian sandstones forming smooth hillsides and few outcrops (Poor 1925). The west-facing, smooth, vertical bluffs rise to a height of nearly 46 m (150 ft) in some places; many large, fallen boulders occur at the base (Nawrot 1974).

Plant communities associated with Pine Hills and Fountain Bluff include lowland, mid-slope, and upland forests. Beech and tulip poplar are often the lowland canopy species in association with sweetgum, chinquapin oak, sugar maple, shagbark hickory, and ashes (Ashby and Kelting 1963, Voigt and Mohlenbrock 1964). Trees and shrubs characteristic of the lowland forest understory include pawpaw, spice bush, redbud, bladdernut, service berry, flowering dogwood, poison ivy, and wild grape.

Dominant trees of midslope include bitternut hickory, black oak, red oak, and white oak; white oak and post oak are indicative of the upland forest community (Voigt and Mohlenbrock 1964). Xeric south- and west-facing slopes and ridges may contain red cedar, blackjack oak, and yellow pine, which is distributed sparsely along the upper chert outcrop (Ashby and Kelting 1963). Understory vegetation of the midslope and ridge communities includes many of those found on the lower slope and hop hornbeam, New Jersey tea, goat's rue, and a characteristic shrub layer of farkleberry and wild azalea on cherty upper slopes (Ashby and Kelting 1963). Honey locust and Kentucky coffee tree are not as abundant as oaks and hickories but they provide an important food source when found near active woodrat sites. Hill prairies are used by a small number of woodrats inhabiting the grassy upper slopes of Pine Hills; characteristic vegetation includes little bluestem, side oats gramma, big bluestem, and Indian grass (Nawrot 1974).

Food habits

Woodrats are considered a generalist herbivore but they consume animal matter on rare occasions (Rainey 1956, Nawrot 1974, Clark et al. 1990, Williams 2000). In southern Illinois, woodrats cache foods during August through October for consumption during winter months (Crim 1961). Items found in caches tend to be less perishable and more nutritious than foods consumed at other times of the year (Reichman 1988, Post 1993). Characteristics of caches vary little among sex and age groups (Post 1993). When open water is unavailable, woodrats subsist on dew, rain, metabolic water and moisture obtained from foods (Murphy 1952).

Woodrats studied at Pine Hills by Crim (1961) used approximately 60 food items throughout the year. Nearly all of these items were deciduous tree leaves and mast, with chinquapin, red, black, and white oak leaves and acorns, maple leaves, and red bud leaves and seed pods accounting for more than 50 percent of all food items (Crim 1961). The relative importance of food items varied seasonally; annuals were consumed in large quantities during April through May; leaves of deciduous trees were the primary food items during June through July (Crim 1961). During autumn, woodrats preferentially collected and stored seed pods from redbud as well as yellow chestnut and red oak acorns and leaves; items cached to a lesser extent included beech, maple, paw paw, winter grape, pin oak, and white oak leaves (Crim 1961). Little food gathering occurred from November through March (Crim 1961).

Food habits reported by Wagle (1996) were less diverse than those noted by (Crim 1961), possibly because of differences in their methods; Crim (1961) examined stomach contents while Wagle (1996) examined scats. Mast, primarily hickory nuts, comprised 61-67% of the woodrat's diet in each season during Wagle's (1996) study. Few herbaceous species were eaten during any season; only Virginia Creeper occurred in fecal samples collected throughout the year (Wagle and Feldhamer 1997).

Behavior

Woodrats are nocturnal, solitary rodents that remain active year-round (Wiley 1971, Nawrot 1974, Hoffmeister 1989). Structures made of bark, sticks, and leaves are the woodrat's base of daily operations (Fitch and Rainey 1956). Such "nests" or "houses" are usually built in crevices or caves and, less frequently, under horizontal ledges of rock bluffs or outcrops (Nawrot 1974). In southern Illinois, woodrats maintain an average of 1.36 houses per individual (Nawrot and Spitzkeit 1986).

Structures vary from a few scattered sticks at the opening of a crevice to piles of debris measuring 1.5 meters (5 feet) long and nearly 1 meter (3 feet) high (Nawrot 1974). Large structures are usually the result of serial occupancy over long periods of time (Crim 1961). Nawrot and Klimstra (1976) noted the presence of both modern (ca 1937-1945) and archaic (ca 600-900 A.D.) artifacts at representative levels within the same structure. Nest chambers ($\geq$2) constructed of shredded bark and dry grass are a common interior feature of woodrat houses (Murphy 1952, Hall 1955, Finley 1958). Novelties such as pieces of broken glass, bottle caps, rusty nails, shotgun shells, old bones, and turtle shells are sometimes collected and stored in houses, contributing to the woodrat's nickname of "pack rat" (Nawrot 1974).

Recent droppings, fresh food cuttings, and/or well-worn trails are indicative of current or recent occupancy of houses (Crim 1961, Nawrot 1974). Woodrats appeared to use 253 of 362 activity centers (70%) located at Pine Hills, Fountain Bluff, and Horseshoe Bluff by Crim (1961); most of these (95.4%) were houses; the remainder included storage and feeding sites as well as combinations of these. Nawrot (1974) estimated that 27% of 229 houses located at Pine Hills were active.

Individual home ranges sometimes overlap (Lay and Baker 1938) but spacing is maintained through mutual intolerance (Fitch and Rainey 1956, Wiley 1971). In northern California, home ranges of *N. fuscipes* overlapped less among adult males (15%) than females (25%); those of males and females overlapped by 28% except during the reproductive season (57%). Crim (1961) reported an average distance of 39 m (127 ft) between adjacent sites of activity at Pine Hills; nearly 38% were <15 m (50 ft) apart whereas 29% were 15-30 m (50-100 ft) apart.

Goertz (1970) reported an average home range size of 0.26 ha (0.64 acres) for males and 0.17 ha (0.41 acres) for females; the maximum home range length was 62.5 m (205 ft) for his study area in Oklahoma. Tate (1970) calculated the mean home range area of 8 adult woodrats using 3 different techniques; estimates varied from 260 m^2 (0.06 acres) for the modified minimum area method to 2,127 m^2 (0.53 acres) for the circular range method. In Missouri, home ranges of males varied from 500-8,500 m^2 (0.12-2.10 acres) while those of females varied from 1,000-3,000 m^2 (0.25-0.74 acres); home range estimates were 95% minimum convex polygons as determined by flourescent pigment tracking (Britzke 1998).

Clark and Clark (1994) noted movements of >150 m (492 ft) in Oklahoma. In Kansas, most movements occurred within 22.9 m (75 ft) of the house; the average maximum distance between successive points of capture was 105 m (345 ft) for 27 adult males and 44 m (143 ft) for 39 adult and subadult females (Fitch and Rainey 1956). Maximum nightly distance traveled from the den averaged 151 m (495 ft) with a range of 29-704 m (95-2,310 ft) for 34 Allegheny woodrats monitored in West Virginia (Castleberry et al. 2001).

At Pine Hills, successive recaptures of 41 individuals occurred 0-87 m (0-285 ft) apart with an average of 25.9 m (85 ft); the average minimum distance between house sites was 25 m (82 ft), indicating that woodrats moved freely between adjacent sites but seldom ventured farther (Nawrot 1974). Movements among sites were less common during Monty's (1997) study of the Pine Hills population; only 34% of woodrats were captured at >1 site; the greatest observed distance between successive captures was 1,477 m (0.92 mi) for an adult male. Nawrot (1974) noted that travel across open spaces was avoided at Pine Hills; woodrats followed protected trails through crevices and under ledges whenever possible.

Woodrats studied in Hunt County, Texas attained densities of 3.3 (winter/spring) to 14.4 (summer) individuals per ha (1.3-5.8 per acre) during a 3-year study (Wilkins 1995). In northern California, Cranford (1977) observed densities of 14 woodrats (*N. fuscipes*) per ha (5.6 per acre) in winter to 20 per ha (8.1 per acre) during late summer. Densities declined from 0.82 woodrats per ha (0.33 per acre) to 0.2 per ha (0.08 per acre) following a mast failure in the lower Mississippi River Basin (Neal 1967).

Reproduction and young

The woodrat is polyestrus with estrous cycles lasting 4-6 days (Asdell 1964). In Illinois, breeding occurs year-round (Monty 1997) but peaks during March to May (Nawrot 1974). Females attain puberty at 5-6 months of age (Asdell 1964). Those born early in the spring sometimes breed in late summer or autumn of the same year (Rainey 1956, Nawrot 1974). Most litters are born during May and early June after a gestation period of approximately 33 to 41 days (Rainey 1956, Nawrot 1974). Nawrot (1974) and Monty (1997) reported evidence of late or second litters in Illinois but believed most females produce only 1 litter per year. In Missouri, woodrats produce 2-3 litters per year (Schwartz and Schwartz 1981). Although based on a small sample size (*n* = 14), the number of young per litter in Illinois (range 2-5, $\bar{x}$ = 3.4, Nawrot 1974) is similar to that reported for other portions of the species' range (range 1-6, $\bar{x}$ = 2.7, Rainey 1956; range 2-7, $\bar{x}$ = 3.2, Goertz 1970).

Young are born blind, nearly naked, and helpless (Layne 1955). The incisors of the young are adapted for attachment to the nipples of the mother (Hamilton 1953); nursing young often remain fixed to the female when she is forced to leave the nest (Nawrot 1974). The young are well furred by the time their eyes open at 15 days of age (Layne 1955), weaned at about 4 weeks of age (Hamilton 1953, Clarke 1973), fully independent by about 10 weeks of age (Layne 1955), and disperse soon after (Post 1999). Juveniles attain full adult body mass at about 8 months of age (Fitch and Rainey 1956).

Demographics

During November, Nawrot (1974) captured slightly more males (52%) than females at Pine Hills. Monty (1997) found nearly even sex ratios for juveniles and adults while that for subadults favored females; females also comprised a greater proportion (58%) of the population at Pine Hills when all age classes were combined (*n* = 283). The sex ratio at Fountain Bluff was approximately 1:1 for all age classes combined (Wagle 1996). Sex ratios reported for other parts of the species' range vary from near equality (Pearson 1952, Goertz 1970, McMurry et al. 1993) to a preponderance of males (55.3%) (Rainey 1956).

Age ratios vary seasonally (Monty 1997). Nawrot (1974) reported 80% of woodrats captured at Pine Hills in November were adults; the remaining 20% was comprised of 7 subadults and 1 juvenile. He (Nawrot 1974) also reported unpublished data from 1959 that showed 69% adults, 28% subadults and 3% juveniles for a fall population of ≥154 woodrats at Pine Hills. A large proportion of woodrats captured at Pine Hills during July 1993 through August 1994 (*n* = 135) were adults (50.4%); subadults comprised 28.1% of captures while juveniles comprised 21.5% (Monty et al. 1995). At Fountain Bluff, Wagle (1996) captured 70 adults (74.5%), 22 subadults (23.4%) and 2 juveniles (2.1%). Age ratios might have been biased because small juveniles (<100 g) do not venture far from nests and, when captured, sometimes escape through the mesh of standard livetraps (Wagle 1996, Monty 1997). However, dispersal of young animals from the study area into surrounding suboptimal habitats probably accounted for relatively low recruitment of woodrats at Pine Hills and Fountain Bluff (Wagle 1996, Monty 1997).

The proportion of individuals that remained at Pine Hills ≥1 year after their initial capture (23%; Monty 1997) was greater than that reported for Kansas (4.3%; Fitch and Rainey 1956) and Oklahoma (~5%; Goertz 1970). On average, the 50 woodrats captured ≥2 times by Goertz (1970) disappeared approximately 63 days after their initial capture (47 days for 28 males and 82 days for 22 females). In Virginia, 19% of juvenile woodrats (*N. magister*) survived from 1 calendar year to the next (i.e., survived overwinter); juvenile males were less likely to be recaptured (10%) than juvenile females (Mengak 2002). For juvenile males, 23 of 39 (59%) were caught only once or on consecutive days in a trap session and never captured again; 16 of 31 (52%) juvenile females were never recaptured (Mengak 2002).

Genetics

Populations at Pine Hills, Fountain Bluff, and Deer Run State Forest, Missouri are genetically different. Ten percent of loci were polymorphic in the Illinois populations compared to 24% for Deer Run State Forest (Monty 1997). Mean heterozygosity was lower in samples from Illinois (range = 0.006-0.054) than Missouri (0.082) (Monty 1997). Monty (1997) concluded that Illinois woodrats have probably experienced significant inbreeding and loss of genetic variation.

Genetic differences occurred among regional populations of *N. magister* as well as subpopulations within regions (Castleberry 2000). Limited gene flow among subpopulations suggested effective dispersal was limited, even when populations were separated by <3 km (1.9 mi) (Castleberry 2000). Average heterozygosity was lower for a population in New Jersey (29%) than across all populations (62%), suggesting management intervention might be needed to restore gene flow after a recent population bottleneck (Castleberry 2000). Genetic characteristics of *N. magister* suggested clusters of geographically proximate colonies or, in some instances, individual colonies should be considered population units for management (Castleberry 2000).

Parasites, diseases and predation

Orchopeas sexdentatus was recovered from nearly 90% of woodrats captured at Pine Hills; infestations varied from a few fleas to >50 (Nawrot 1974). The common American dog tick (*Dermacentor variabilis*) occurred on about 18% of woodrats examined during October through May; the number of ticks per individual varied from 1 to 16 (Nawrot 1974). Crim (1961) mentioned that parasites of woodrats in southern Illinois included fleas, ticks, and warbles but he did not identify species.

Mortality caused by larva migrans of the nematode *Baylisascaris procyonis* has been implicated as a possible factor in the decline of *N. magister* because woodrats collect and store foods, including undigested seeds found in raccoon scats (Beans 1992). Eggs of *B. procyonis* remain viable for years and are resistant to all common disinfectants (Kazacos and Boyce 1989). Infection causes lethargy, loss of muscle control, torticollis, ataxia, and nystagmus, eventually progressing to stupor, extensor rigidity, coma, and death (Kazacos et al. 1981, Kazacos 1986, Kazacos and Boyce 1989).

Raccoons inhabiting northern latitudes are more likely to be infected with *B. procyonis* than those in the southern United States (Jordan and Hayes 1959, Harkema and Miller 1964, Schaffer et al. 1981). In central Illinois, Snyder and Fitzgerald (1985, 1987) identified *B. procyonis* in 93% of juvenile raccoons and 55% adults; Hungerford and Zachary (1995) reported that 70% of juvenile raccoons, 31% of yearlings and 28% of adults were actively shedding eggs of *B. procyonis*. Infection rates for southern Illinois were low (5% of 60 raccoons), leading the authors (Birch 1993, Birch et al. 1994) to conclude that parasitism by *B. procyonis* might not be a problem for woodrats translocated to sites formerly occupied by this species in the eastern part of the

Shawnee National Forest.

Crim (1961) listed 21 potential predators of woodrats in southern Illinois but he considered snakes (*Coluber constrictor*, *Elaphe obsoleta*, *Agkistrodon piscivorous*, *A. contortrix*, *Crotalus horridus*) the greatest threat because they could enter woodrat houses easily. Fitch and Rainey (1956) believed the woodrat was an important prey species of the timber rattlesnake. However, Perez et al (1978) reported evidence of natural resistance to rattlesnake (*C. atrox*) venom in *N. micropus*.

Management

Monitoring

Studies conducted in the western United States documented linear relationships between counts of active woodrat (*N. fuscipes*) houses along line or belt transects and population estimates derived from mark-recapture data (Willy 1992, Hamm 1995, Vreeland and Tietje 1999, Hamm et al. 2002). However, line or belt transects are probably a poor choice for monitoring woodrats in southern Illinois. To obtain reliable estimates of density, objects and lines from which they are sampled must be distributed randomly in the study area (Burnham et al. 1980). Violations of these assumptions seem likely where active houses are distributed patchily along linear features such as rock bluffs or outcrops; transects located randomly in these areas would be difficult or unsafe to traverse.

Crim (1961) and Nawrot (1974) attempted to count all active houses at sites in southern Illinois because this task was possible logistically, the method was non-invasive, data could be compared directly to past studies, and their efforts provided information about many attributes of woodrats, including relative abundance. House counts are conducted most efficiently in early spring at first emergence of green vegetation and can be used to derive conservative estimates of population size using a nest to woodrat ratio of 1.36:1 (Nawrot and Spitzkeit 1986).

Monty (1997) used mark-recapture methods to determine the minimum number of individuals known alive at sites in southern Illinois. This approach has been used elsewhere (e.g., Hamm et al. 2002) when low numbers of captures prevented estimation of true population size. Minimum number known alive is a negatively biased estimate (Nichols and Pollack 1983) without strict assumptions about the distribution of individuals or their probability of capture (Caughley and Sinclair 1994). Monty (1997) preferred this method to estimates derived from counts of active houses because houses were not always evident, the number of houses per woodrat might have varied with density of the population, and mark-recapture data provided estimates of survival and other metrics.

Monty (1997) used a standard protocol of 40 traps set for 3 consecutive nights to determine whether woodrats were present at a site and obtain an estimate of the minimum number of individuals known alive. In Indiana, Cudmore (1985) noted few new captures of *N. magister* after he set 44 traps for 3 nights, waited a week, then set traps for 2 nights. More recently, the Indiana Department of Natural Resources used a protocol of 40 traps (range 15-60) set for 2 nights at each of 15 sites where *N. magister* was known or thought to occur (Johnson and Madej

1993); staff recommend conducting surveys every 4-5 years to detect changes in this species' status (Johnson et al. 1997). The State of Kentucky monitored woodrats bimonthly at 3 sites using a protocol of 40 traps set for 2 consecutive nights (Thomas 2001). Britzke and Robbins (2002:126) suggested *N. floridana* should be monitored "on a regular basis" in Missouri but they made no specific recommendations on periodicity of such efforts.

Habitat

In Illinois, destruction of critical habitat seems unlikely because all sites occupied by woodrats are owned and managed by the U.S. Forest Service as part of the Shawnee National Forest (Monty 1997). The Pine Hills' designation as a Research Natural Area provides additional protection for this important population (Monty and Feldhamer 2002). Monty and Feldhamer (2002) recommended acquisition of private land adjacent to the woodrat population at Fountain Bluff in Jackson County to prevent disturbance or habitat loss.

Woodrats are thought to exhibit metapopulation structure (Monty 1997, Castleberry et al. 2000). A metapopulation consists of local populations which occur in discrete patches of habitat and are linked by dispersal. Theoretically, the fates of individual colonies are relatively unimportant except as they relate to an overall equilibrium or positive ratio of colonizations to extinctions at habitat patches. This concept implies woodrats will benefit from conservation practices applied at a landscape scale to allow individuals to disperse successfully from 1 patch to the next and on a local scale (i.e., individual habitat patches) to provide suitable conditions for colonization and recruitment (Castleberry et al. 2000). Barriers to dispersal include artificial reservoirs, croplands, residential developments, stone quarries, and highways (Nawrot and Klimstra 1976).

Balcom and Yahner (1996) believed forest fragmentation did not play a role in the decline of *N. magister* in Pennsylvania; percentages of deciduous forest, total forest and urban cover were similar for occupied, unoccupied historical, and reference sites. They (Balcom and Yahner 1996) speculated changes in forest composition caused by diseases (e.g., American chestnut blight), pests (e.g., reduced recruitment of oaks caused by gypsy-moth defoliation and heavy browsing by white-tailed deer), and anthropogenic influences (e.g., a shift toward later-successional, shade-tolerant species caused by fire suppression and reduced logging) affected habitat suitability for woodrats by reducing availability of mast. Balcom and Yahner (1996) also speculated woodrat colonies located near residential and agricultural cover types might be more prone to extinction than those found in comparatively remote forested habitats where great horned owls and raccoons were less abundant.

Clearcutting had minimal impact on woodrat (*N. magister*) movements, home range, and habitat use when sufficient intact forest was retained adjacent to colonies in the central Appalachians of West Virginia (Castleberry et al. 2001). Woodrats used forested and clearcut areas in proportion to their availability (Castleberry et al. 2001) and exploited new sources of foods on clearcut areas such as succulent growth from hardwood stump sprouts and soft mast from blackberry, grape, and blueberry plants (Castleberry 2000). Selective removal of large (>40 cm (15.8 in) diameter at breast height) mast-producing species, mostly northern red oak and black cherry, represented the greatest disturbance to woodrats from forest management (Castleberry et al. 2001). The authors (Castleberry et al. 2001) recommended timber harvest strategies that (1) retain intact forest immediately covering rock outcrops and on 1 adjacent side, (2) provide a forested buffer between rock outcrops and timber harvests, and (3) promote growth of mast-producing trees and understory vegetation. In less intensively managed forests (i.e., those with little or no commercial timber harvest), measures such as crop tree release and stand thinning are recommended because these practices help to stimulate acorn production and maintain oaks as dominant species (Castleberry et al. 2002). Nawrot (1974) found hill prairies represented an important habitat type for a small number of woodrat nests located on the grassy upper slopes of Pine Hills. Therefore, practices which seek to maintain these habitats are probably appropriate.

Translocation

Releases of translocated wild or captive-raised woodrats at unoccupied sites in the Shawnee National Forest have been proposed to increase genetic diversity, distribution, and abundance of this species in Illinois (Nawrot 1974, Nawrot and Spitzkeit 1986, Feldhamer 1994, Monty 1997, Illinois Department of Natural Resources 2000). Likely locations include areas near Otter Pond (T11S R3W Section 28) and Section 16 (T11S R3W) in Union County (Nawrot and Spitzkeit 1986), as well as Lusk Creek (T11S R6E Section 28), Indian Kitchen (T11S, R6E, Section 34), and One Horse Gap (T11S R6E Section 34) in Pope County (Feldhamer 1994). Approaches recommended by Feldhamer (1992, 1994) are consistent with the Illinois Endangered Species Protection Board's Policy on Translocation of Endangered and Threatened Animal Species (Appendix I).

No translocations of *N. f. illinoensis* have been reported. Nineteen Key Largo woodrats released in a previously unoccupied area of Lignum Vitae Key, Florida increased to a population of approximately 85 individuals; this effort was considered a success (Brown and Williams 1971, Barbour and Humphrey 1982). Woodrats (*N. magister*) released in Pennsylvania moved to and occupied new dens more often than residents during the first 10 weeks post-release; residents were more transient than introduced woodrats during the second 10 weeks (Corbett and Shinkle 1997). The authors (Corbett and Shinkle 1997) suggested woodrats should be released at least 10 weeks before winter to allow them to establish permanent residences with food caches; they also suggested release sites should occur >28m (>92 ft) apart because this was the minimum distance observed between occupied den sites.

Attempts to re-establish *N. magister* at a site in Ohio failed when only 6 of 42 individuals survived >100 days (Schlie 1985). Schlie (1985) speculated long-distance movements ($\bar{x}$ = 100-615m for various release groups; 328-2,018ft) that resembled dispersal behavior contributed to high mortality and might have been caused by territoriality resulting from high initial densities relative to available habitat (>3.3 woodrats per ha; >1.3 per acre). Lack of suitable crevices, defined as generally narrow (<30 cm; <11.8 in), deep (>10 m; >32.8 ft), multi-chambered, possessing >1 opening, and located along continuous outcrops was also perceived as a problem (Schlie 1985). Gentle release methods allowed woodrats to survive longer ($\bar{x}$ = 61 days) than direct methods ($\bar{x}$ = 13 days) (Schlie 1985). Gentle releases occurred after leaf-out; woodrats were held at release sites for ≥7 days in holding cages with food, water, nest material, and nest boxes available; they received supplemental food for >4 weeks after holes were cut in the mesh to allow their escape, and domestic chickens were tethered in the vicinity to distract predators (Schlie 1985).

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RECOVERY GOAL, OBJECTIVES AND CRITERIA

by

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Goal: **Insure the long-term viability of the eastern woodrat in Illinois by increasing genetic heterogeneity of extant populations, establishing populations at sites where woodrats occurred historically, monitoring population levels, and managing key habitats.**

Justification:

Recovery of the eastern woodrat is consistent with Objective 1.1.2.3 of the Department's Strategic Plan (Illinois Department of Natural Resources 2002) and it's legislatively mandated responsibility to "take all measures necessary for the conservation, distribution, introduction and restoration of birds and mammals" (520 Illinois Compiled Statutes 5/1.10).

Objective 1: **Reclassify the eastern woodrat from state endangered to state threatened.**

Performance Indicators: Objective 1 is met when a stable or increasing metapopulation of $\geq$50 individuals (fall estimate) is established in an unoccupied part of the woodrat's historical range on the eastern part of the Shawnee Hills Natural Division (i.e., Johnson, Saline, Gallatin, Pope, or Hardin counties) and persisted $\geq$4 years after translocations have ceased.

Justification: Illinois occurs at the northern periphery of the eastern woodrat's range. This species was never distributed widely nor particularly abundant in the state; it occurred mostly along limestone bluffs of the Mississippi River and sandstone outcrops of the Shawnee Hills (Nawrot and Klimstra 1976). Woodrats have persisted at low levels at Pine Hills in Union County for >50 years (Swayne 1949, Layne 1958, Crim 1961, Nawrot 1974, Monty 1997). Recent discovery of individuals at Fountain Bluff, Horseshoe Bluff, Cripps Bend, and Little Grand Canyon in Jackson County (Monty et al. 1995) suggests colonies at Pine Hills and its satellites probably constitute a stable to increasing metapopulation.

Searches of sites where woodrats occurred historically in the Shawnee Hills failed to document their presence (Feldhamer 1994). Researchers recommended translocating woodrats to $\geq$1 of these sites to reclaim part of the species' former range and reduce risks of extirpation caused by a fire, tornado, or other catastrophic event at Pine Hills (Feldhamer 1994, Monty 1997).

Criteria: Feldhamer (1992) proposed the following criteria as evidence of a successful translocation: (1) reproduction, (2) new nest construction, (3) survival of some individuals to a normal lifespan of 2-3 years.

Reproduction may be documented by $\geq$1 of the following:

A) Capture of juvenile woodrats
B) Capture of gravid or lactating females
C) Capture of untagged individuals at sites where releases occur

Population size may be assessed by $\geq$1 of the following:

A) Minimum number of individuals known alive (determined by mark-recapture)
B) Estimates of population size (determined by mark-recapture)

Lifespan may be determined by $\geq$1 of the following:

A) Mark-recapture
B) Radiotelemetry

Strategies: Release translocated wild woodrats at $\geq$1 unoccupied site(s).

Actions: ***Task 1. Evaluate accessible sites where Nawrot and Klimstra (1976) found evidence of historical habitation by woodrats.***

Detail: Nawrot and Klimstra (1976) identified 24 sites where they found direct evidence (e.g., skeletal remains, scats, abandoned nests) of past habitation by woodrats. All such sites currently owned or managed by public agencies such as U.S. Forest Service, Illinois Department of Natural Resources, or local units of government will be searched for the presence of woodrats and evaluated qualitatively for habitat suitability as described by Feldhamer (1994). Sites that occur on private properties will be evaluated if landowners or tenants grant access.

Task 2. Identify additional sites with suitable habitat.

Detail: Nawrot (1974) listed 40 sites in Jackson, Union, Williamson, Johnson, Saline, Pope, Gallatin, and Hardin counties with seemingly suitable habitat but no evidence of past habitation by woodrats. Nawrot (1974) speculated woodrats occurred at some of these sites but artifacts were destroyed by weathering and disturbance. His assessment suggests suitable habitat might be more widespread than sites evaluated under Task 1 of this recovery plan. Digital landscape data and a geographic information system will be used to identify sites with rock bluffs or outcrops and other characteristics of suitable habitat.

Task 3. ***Classify sites according to their quality and spatial arrangement.***

Detail: Individual sites and clusters of sites that appear large enough to sustain a viable metapopulation of ≥50 woodrats will be visited and evaluated more closely using methods described by Feldhamer (1994). Results will be combined with those of Task 1 and past studies (Nawrot and Spitzkeit 1986, Feldhamer 1994) to classify areas (a site or group of proximate sites) as excellent, good, fair, or poor candidates for translocations based on their size, relative quality, and spatial arrangement (i.e., proximity to other sites). We will also use landscape-level information to identify possible corridors for linking metapopulations in the Pine Hills and Shawnee Hills.

Task 4. ***Seek public input.***

Detail: We will seek comments on recovery activities using existing mechanisms such as regularly scheduled public meetings of the Illinois Endangered Species Protection Board and a notice published in the Shawnee Quarterly, a publication distributed by the Forest Service.

Task 5. ***Translocate woodrats to suitable but unoccupied habitats; identify successful, efficient protocols for releases***.

Detail: Factors that might affect survival and reproduction of translocated individuals include stress caused by capture, handling, and transport; sex and age ratios of released individuals; numbers of individuals released; timing (as related to food availability, cache behavior, and reproductive status); release methods (e.g., hard or gentle; pulse or mass); and extrinsic variables such as weather and predation (Feldhamer 1992). Release strategies will generally follow those recommended by Feldhamer (1992; Appendix I). During the first year, we will attempt to optimize survival and reproduction by capturing animals in spring, transporting and releasing them the day after their capture, and providing supplemental nest materials and food at release sites. If this approach is deemed successful, we continue to use it; if not, we will evaluate "softer" release strategies.

Objective 2: Increase genetic heterogeneity of the Pine Hills metapopulation.

Performance Indicators: Objective 2 is met when woodrats are translocated successfully to Pine Hills from out-of-state sources or, if funding allows, studies document increases in indices of heterozygosity.

Justification: Monty (1997) concluded Illinois woodrats had probably experienced significant inbreeding and loss of genetic variation. Possible effects of inbreeding include depressed growth, reproduction, and survival (Templeton and Read 1983, Ralls et al. 1988, Bouzat et al. 1998, Bodkin et al. 1999).

Criteria: Increased genetic variation may be assumed to occur if ≥10 woodrats captured from another state and released at Pine Hills or its satellites are known to survive through the peak breeding season of March to May. If we obtain additional funding, we will monitor the average proportion of loci for which an individual is heterozygous (mean heterozygosity) and the mean number of alleles per locus before and after releases. Benchmarks from Monty's (1997) study of the proportion of polymorphic microsatellite loci in populations from Illinois (10%) and Missouri (24%) also provide meaningful comparisons.

Strategies: Release translocated wild woodrats at Pine Hills.

Actions: ***Task 6. Release 10-15 woodrats per year for 2-3 years at Pine Hills.***

Detail: Feldhamer (1992) recommended releases of 10-15 woodrats per site to promote adequate survival and genetic variability. His recommendation is consistent with that of Leberg (1990), who stated founding populations of ≥10 individuals can retain most (≥95%) heterozygosity of the source population. Therefore, we believe genetic transfer from a relatively small number of translocated individuals will accomplish our goal of supplementing the genetic make-up of the Pine Hills metapopulation without swamping it.

Objective 3: Delist the eastern woodrat from state threatened status.

Performance Indicators: Objective 3 is met when (1) genetic heterogeneity of the Pine Hills metapopulation has increased, (2) a stable or increasing metapopulation has been documented at Pine Hills and associated sites for ≥4 consecutive years, (3) a stable or increasing metapopulation consisting of ≥50 individuals (fall estimate) has persisted on the eastern side of the Shawnee Hills Natural Division for ≥4 years after translocations have ceased, and (4) ≥2 additional populations consisting of ≥30 individuals each have persisted ≥2 years after translocations have ceased.

Justification: Enhancing genetic variability of the Pine Hills metapopulation eliminates the only perceived risk supported by scientific data. Establishing a second viable metapopulation in the Shawnee Hills Natural Division eliminates foreseeable risks of the species becoming endangered, especially given that many or most key habitats are protected through public ownership. Establishing woodrats at ≥2 key sites that promote linkage of populations in the Pine Hills and Shawnee Hills will help to sustain genetic vigor and further improve distribution and abundance of the species.

Criteria: Criteria specified for objectives 1 and 2 will be used to evaluate progress toward de-listing the eastern woodrat from state threatened status.

Strategies: Promote linkage of metapopulations in the Pine Hills and Shawnee Hills by establishing colonies along the best existing corridors.

Actions: ***Task 7. Release wild woodrats at $\geq$2 unoccupied sites that occur in likely corridors between the Pine Hills and Shawnee Hills.***

Detail: We plan to duplicate successful release protocols identified by Task 4 at $\geq$2 sites classified as excellent candidates for releases by Task 3. Our choice of sites will consider barriers to dispersal, including distances between sites with suitable habitat, to best facilitate linkage of the Pine Hills and Shawnee Hills metapopulations.

Objective 4: Implement a long-term monitoring program.

Performance Indicators: Objective 4 is met when the Department of Natural Resources implements a long-term monitoring program capable of detecting significant changes in the woodrat's status.

Justification: Research conducted by Southern Illinois University during the first 5 years of this recovery effort will provide estimates of abundance. Monitoring efforts must continue past this period of time to assess progress toward the recovery goal and provide a scientific basis for management actions consistent with the species' status.

Criteria: Survey accessible sites every 4-5 years using standard mark-recapture methods.

Strategies: Identify efficient sampling protocols. Train staff to conduct surveys safely and effectively. Schedule surveys of individual sites on a 4-5-year rotation to reduce conflicts with other staff assignments.

Actions: ***Task 8. Identify efficient protocols for monitoring abundance.***

Detail: Protocols for monitoring programs differ mainly in the number of consecutive nights during which traps are set. For example, Wagle (1996) and Monty (1997) set an average of 40 traps for 3 consecutive nights while the Indiana Department of Natural Resources monitored *N. magister* using a standard protocol of 40 traps set for 2 nights (Johnson et al. 1997). The latter approach provides obvious logistical advantages but probably underestimates the minimum number of individuals known alive (Johnson et al. 1997). Using a standard protocol of approximately 40 traps set for 3 nights per session, we will analyze capture data from Tasks 4-6 to determine the extent to which a 2-night protocol would have underestimated the minimum number of individuals known alive. Results will provide a basis for choosing a 2-night or 3-night protocol for long-term monitoring efforts.

Task 9. Train staff likely to participate in long-term monitoring efforts.

Detail: Staff likely to participate in monitoring efforts should be trained to apply methods according to standard protocols to insure the greatest accuracy and precision of results. Training sessions should also provide instructions on safety because sites occupied by woodrats tend to present several hazards such as loose or falling rocks and venomous snakes.

Task 10. Conduct surveys to monitor changes in the status of woodrats.

Detail: The first surveys conducted by IDNR staff should be synchronized with research activities to provide a smooth transition. Staff should monitor individual sites on a 4-5-year rotation to reduce conflicts with other assignments.

Objective 5: Evaluate and, where possible, implement appropriate habitat management practices.

Performance Indicators: Objective 5 is met when agencies such as the Forest Service and IDNR consider impacts of habitat management policies and practices when planning activities that affect sites where woodrat populations occur on agencies' properties.

Justification: In Illinois, forest acreage dominated by maples has increased >40-fold since 1962 while acreage dominated by oaks has declined 14% (Illinois Department of Energy and Natural Resources and The Nature of Illinois Foundation 1994). This trend, caused mostly by fire suppression and other anthropogenic influences, is likely to affect the long-term quality of habitat occupied by woodrats because they consume mast almost exclusively (61-67%) during all seasons (Wagle and Feldhamer 1997). Silvicultural practices that promote regeneration of oak-hickory forests are generally considered beneficial, including prescribed fire and timber stand improvement. Timber harvests that (1) retain intact forest immediately covering rock outcrops and on 1 adjacent side, (2) provide a forested buffer between rock outcrops and timber harvests, and (3) promote growth of mast-producing trees and understory vegetation cause no immediate harm to woodrats and improve long-term habitat quality (Castleberry et al. 2001). In areas where little or no commercial timber harvest occurs, measures such as crop tree release and stand thinning are recommended because these practices help to stimulate acorn production and maintain oaks as dominant species (Castleberry et al. 2002).

Criteria: Participate in planning activities that guide management of sites occupied by woodrats.

Strategies: Provide technical expertise during planning activities coordinated by the Forest Service, . Encourage use of silvicultural practices that benefit the eastern woodrat. If possible, evaluate responses of woodrats to specific forest management practices.

Actions: ***Task 11. Evaluate responses of woodrats to selected silvicultural practices.***

Detail: Monty (1997) observed woodrats living in brush piles that remained after timber stand improvement. She suggested these brush piles might play an important role as "rest stops" for dispersing woodrats, especially where rock bluffs or outcrops were absent (Monty 1997). This concept, recognized elsewhere as a possible management technique (Bunch and Dye 1999), merits investigation because dispersal figures prominently in the ecology and recovery of this species. Our ability to accomplish this task will depend greatly on availability of funding and opportunities to apply silvicultural practices as part of a valid experimental design.

Task 12. Participate in planning activities that guide habitat management practices on the Shawnee National Forest.

Detail: Most areas that are inhabited or likely to be inhabited by woodrats occur within the boundaries of the Shawnee National Forest. Therefore, policies developed and implemented by the U.S. Forest Service to guide resource management and recreational activities affect the long-term viability of the eastern woodrat in Illinois. Participating in planning activities that shape management policies provides opportunities to advocate beneficial practices such as prescribed burns, timber stand improvement, and harvest to maintain oak-hickory forests.

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Appendix I. Compliance of proposed actions with the Illinois Endangered Species Protection Board's draft policy on translocation of endangered and threatened animal species.

BASIC CRITERIA

Habitat suitable for the species in both quality and quantity is present in the area of the proposed translocation

Nawrot and Klimstra (1976) found direct evidence of past habitation by woodrats (e.g., skeletal remains, scats, houses) at 24 unoccupied sites in Jackson, Union, Johnson, Pope, Gallatin, and Hardin counties. An additional 40 sites in Jackson, Union, Williamson, Johnson, Saline, Pope, Gallatin, and Hardin counties seemed to offer suitable habitat but provided no direct evidence of past habitation, possibly because artifacts were destroyed by weathering and disturbance (Nawrot 1974).

Translocation of the species will not have negative effects on extant Illinois populations of the same species or other native species

Monty (1997) concluded Illinois woodrats had probably experienced significant inbreeding and loss of genetic variation. Possible effects of inbreeding include depressed growth, reproduction, and survival (Templeton and Read 1983, Ralls et al. 1988, Bouzat et al. 1998, Bodkin et al. 1999). Therefore, translocation of individuals from out-of-state sources is likely to be beneficial.

Depending on the status of the Pine Hills population, we will remove approximately 10-15 woodrats per year to supplement releases at other sites. Our goal is to preserve the Illinois genotype to the degree possible. Adults comprise a large proportion of populations at Pine Hills (Monty 1997) and Fountain Bluff (Wagle 1996), suggesting recruitment of younger age classes is limited. Therefore, removal of subadults and juveniles for translocation should have little effect on the source population. We also plan to replace individuals removed from Pine Hills with individuals from out-of-state populations (Task 5; Release 10-15 woodrats per year for 2-3 years at Pine Hills).

Required approvals from other State and Federal agencies have been secured

State agencies in Missouri and Arkansas have granted verbal approval to capture woodrats within their jurisdictions and transport them to Illinois. A permit from the regional office of the U.S.

Forest Service will be required for capture and translocation of woodrats at Pine Hills; we will apply for this permit before work is scheduled to begin in spring of 2003.

If a State or Federal recovery plan for this species has been developed, the translocation is compatible with the goals, objectives, and methods of the recovery plan

No Federal recovery plan exists for this species. Translocation is specified by tasks 5 (Translocate woodrats to suitable but unoccupied habitats; identify successful, efficient protocols for releases), 6 (Release 10-15 woodrats per year for 2-3 years at Pine Hills) and 7 (Release wild woodrats at >2 unoccupied sites that occur in likely corridors between the Pine Hills and Shawnee Hills) of the State recovery plan.

The translocation plan includes recommended methods and procedures for monitoring and management of released individuals

Methods will generally follow those proposed by Feldhamer (1992):

1. Obtaining individuals to reintroduce

    a) appropriate subspecies (*N. f. illinoensis*)
    b) ideally from the same latitude as the release sites

2. Population characteristics of reintroduced individuals

    a) minimum of 10-15 woodrats/site.
    b) appropriate sex ratio (ideally 2 females:1 male)
    c) appropriate age ratio (ideally 2 adults:1 juvenile)

3. Handling and transport

    a) transport and release animals within 24 hours of their capture
    b) transport animals in individual cages
    c) provide food, water, nesting material

4. Mechanics of release: time period, area, season

    a) release sites should offer numerous cave-like depressions and ledges in the overall rocky outcrops; they should be located well above potential flooding
    b) food should be readily available (buds, leaves, stems, fruits, mast, seeds, succulent herbs)
    c) males are intolerant of other males; release strategies should seek to minimize interactions through distance and availability of escape cover
    d) release in spring: females may already be pregnant; also insures warm weather as individuals establish residency

5. Monitoring

a) employ radiotelemetry only as needed to satisfy specific study objectives
b) use mark-recapture to determine minimum number of individuals known alive; information needs during early phases of recovery will likely be greater than those required for a long-term monitoring program

6. Criteria to evaluate "success"

a) occurrences of new, juvenile individuals as evidence of reproduction
b) new nest construction as evidenced by fresh cuttings, droppings and trails
c) survival for normal life span of 2-3 years
d) ultimately, a reproductively viable, increasing population on the site 5-10 years after introduction

7. Extrinsic factors beyond management control

a) extreme cold winters following introduction
b) predation
c) widespread mast failure caused by epidemic diseases or parasites (e.g., gypsy moth infestation)

The target area for the translocation effort is known to have been inhabited historically by the species

N. f. illinoensis occurs in extreme southern Illinois, southeastern Missouri, western Kentucky and Tennessee, eastern Arkansas, most of Mississippi and Alabama, and the panhandle of Florida (Schwartz and Odum 1957). Sites occupied by woodrats in southern Illinois are isolated from the nearest known populations 120.7 km (75 mi) to the west in Missouri and 136.8 km (85 mi) to the south in Tennessee (Nawrot and Spitzkeit 1986). Skeletal remains establish a prehistoric (c.a. 8500-1500 BC) distribution in Illinois which included portions of Randolph and Monroe counties (Parmalee 1959, Parmalee et al. 1961), approximately 104.6 km (65 mi) north of where woodrats now exist in the state.

Nawrot and Klimstra (1976) found direct evidence of past habitation by woodrats (e.g., skeletal remains, scats, houses) at 24 sites in Jackson, Union, Johnson, Pope, Gallatin, and Hardin counties, Illinois; they also documented extant populations at Pine Hills and Fountain Bluff. Historical records for Illinois also include Chalk Bluff (Layne 1958) in Jackson County, Burden Falls in Pope County (Layne 1958), north of Rosiclare in Hardin County, and Horseshoe Lake in Alexander County (Wetzel 1947). Swayne (1949) reported a specimen from southern Jackson County. Specimens archived at the Illinois Natural History Survey include 17 collected from Union County during 1940 through 1960 and 1 collected from Alexander County in 1957 (Joyce Hofmann, Illinois Natural History Survey, personal communication). Nawrot (1974) listed 40 sites in Jackson, Union, Williamson, Johnson, Saline, Pope, Gallatin, and Hardin counties that seemed to offer suitable habitat but provided no direct evidence of past habitation; he speculated that woodrats had probably occurred at these sites but artifacts were destroyed by weathering and disturbance.

DETAILED REVIEW

Regional population trends of the species

N. f. illinoensis is classified as a state endangered species in Illinois, a species of concern in South Carolina and a species in need of management in Tennessee; elsewhere its status is unknown or considered secure (Monty and Feldhamer 2002, Britzke 1998).

Available sources of animals to be imported

N. f. illinoensis occurs in extreme southern Illinois, southern Missouri, western Kentucky and Tennessee, eastern Arkansas, most of Mississippi and Alabama, and the panhandle of Florida (Schwartz and Odum 1957). State agencies in Missouri and Arkansas have agreed verbally to allow us to capture woodrats in their jurisdictions.

Status of remaining suitable habitat

Most sites with historical records of woodrats are secure because they are managed by public agencies such as the U.S. Forest Service, Illinois Department of Natural Resources or local governments (e.g., City of Carbondale). Replacement of oak-hickory forests with shade-tolerant dominant species such as maple and beech might reduce long-term habitat suitability because woodrats feed almost exclusively on mast.

Effects on agriculture, public health, or other non-conservation interests

We anticipate no negative impacts on agriculture, public health, or other non-conservation interests. Woodrats are native to the recovery area and will be obtained from the nearest extant populations.

Review of translocation attempts in other areas

No translocations of *N. f. illinoensis* have been reported. Nineteen Key Largo woodrats released in a previously unoccupied area of Lignum Vitae Key, Florida increased to a population of approximately 85 individuals; this effort was considered a success (Brown and Williams 1971, Barbour and Humphrey 1982). Woodrats (*N. magister*) released in Pennsylvania moved to and occupied new dens more often than residents during the first 10 weeks post-release; residents were more transient than introduced woodrats during the second 10 weeks (Corbett and Shinkle 1997). The authors (Corbett and Shinkle 1997) suggested woodrats should be released at least 10 weeks before winter to allow them to establish permanent residences with food caches; they also suggested release sites should occur >28m (>92 ft) apart because this was the minimum distance observed between occupied den sites.

Attempts to re-establish *N. magister* at a site in Ohio failed when only 6 of 42 individuals survived >100 days (Schlie 1985). Schlie (1985) speculated long-distance movements ($\bar{x}$ = 100-615m for various release groups; 328-2,018ft) that resembled dispersal behavior contributed to high mortality and might have been caused by territoriality resulting from high initial densities relative to available habitat (>3.3 woodrats per ha; >1.3 per acre). Lack of suitable crevices, defined as generally narrow (<30 cm; <11.8 in), deep (>10 m; >32.8 ft), multi-chambered, possessing >1 opening, and located along continuous outcrops was also perceived as a problem (Schlie 1985).

Gentle release methods allowed woodrats to survive longer ($\bar{x}$ = 61 days) than direct methods ($\bar{x}$ = 13 days) (Schlie 1985). Gentle releases occurred after leaf-out; woodrats were held at release sites for $\geq$7 days in holding cages with food, water, nest material, and nest boxes available; they received supplemental food for >4 weeks after holes were cut in the mesh to allow their escape and domestic chickens were tethered in the vicinity to distract predators (Schlie 1985).

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Appendix II.. Proposed time schedule for tasks specified by the eastern woodrat recovery plan.

Task	FY03	FY04	FY05	FY06	FY07	FY08 & beyond
Evaluate accessible sites where Nawrot and Klimstra (1976) found evidence of historical habitation by woodrats.	✘					
Identify additional sites with suitable habitat.	✘	✘				
Classify sites according to their quality and spatial arrangement.		✘				
Translocate woodrats to suitable but unoccupied habitats; identify successful, efficient protocols for releases.	✘	✘	✘			
Release 10-15 woodrats per year for 2-3 years at Pine Hills.		✘	✘			
Release wild woodrats at >2 unoccupied sites that occur in likely corridors between the Pine Hills and Shawnee Hills.				✘	✘	
Identify efficient protocols for monitoring abundance.	✘	✘	✘	✘		
Train staff likely to participate in long-term monitoring efforts.					✘	
Conduct surveys to monitor changes in the status of woodrats.					✘	✘
Evaluate responses of woodrats to selected silvicultural practices.			✘	✘	✘	
Participate in planning activities that guide habitat management practices on the Shawnee National Forest.	✘	✘	✘	✘	✘	✘