Conservation Assessment
for
The Eastern Woodrat, (Neotoma floridana) and
The Allegheny Woodrat (Neotoma magister)

Eastern woodrat

Allegheny woodrat

USDA Forest Service, Eastern Region

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This Conservation Assessment was prepared to compile the published and unpublished information on the subject taxon or community; or this document was prepared by another organization and provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service – Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203

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EXECUTIVE SUMMARY

Woodrat populations are declining across the eastern United States. Within Illinois and Indiana, many formerly occupied sites are now vacant and extant populations are smaller. This conservation assessment provides information regarding woodrat natural history, status, distribution, potential threats, conservation, and potential research topics.

The Allegheny woodrat (*Neotoma magister*) has experienced population declines during the last 20 years across the northeastern portion of its geographic range and has been extirpated in New York and Connecticut. New Jersey and Ohio each support only 1 known population. Allegheny woodrats are endangered in Indiana. Surveys conducted between 1991 and 1996 resulted in the capture of a total of 95-123 individuals per year across 11-12 sites in Harrison and Crawford counties.

Four principal causes for population declines have been suggested: increased predation by great horned owls (*Bubo virginianus*), changes in the landscape such as forest fragmentation and changing forest composition, reduced availability of acorns and American chestnuts (*Castanea dentata*), and infection and mortality from a nematode parasite, *Baylisascaris procyonis*, carried by raccoons (*Procyon lotor*). Woodrats are an intermediate host for *B. procyonis* and may ingest the nematode eggs while collecting dried raccoon feces. Infection leads to lethargy, loss of muscle control, and eventual death. *B. procyonis* is a mortality factor in woodrats in Indiana, New York, New Jersey, and Pennsylvania.

Eastern woodrats (*Neotoma floridana*) are listed as endangered, threatened or of special concern in only 5 of the 17 states in which they occur. However, state status designations may not be current because very little woodrat research is being conducted in areas where woodrats are presumed to be common. It is notable that the states with documented population declines are on the periphery of the range. Eastern woodrats are endangered in Illinois. It is estimated that populations in the eastern part of the Shawnee National Forest in Illinois were extirpated about 50-75 years ago. Four extant Illinois populations remain: Pine Hills, Union County (283 captured 1993-1996), Fountain Bluff (94 captured 1994-1995), Little Grand Canyon (21 captured 1994-1995), and Horseshoe Bluff (19 captured 1994-1995), Jackson County.

Three possible causes for population declines have been suggested for eastern woodrats: severe winter weather, predation, and poor acorn crops. There are no published reports of eastern woodrat mortality due to infection with *B. procyonis,* although little information exists on the parasite's prevalence in raccoons living in the vicinity of *N. floridana* populations.

Four principal conservation measures or research topics are discussed: further protection of habitat, monitor populations, investigate reasons for declines, and consider reintroductions into formerly occupied sites with low *B. procyonis* contamination. Woodrats are unlikely to naturally repopulate isolated areas due to human-influenced changes in landscapes including agricultural use, housing developments, and roads. Reintroduction into previously inhabited sites may aid in local recovery projects.

ACKNOWLEDGEMENTS

We thank Scott Johnson, Indiana Department of Natural Resources Division of Fish and Wildlife, and Steven Thomas, National Park Service, for providing progress reports and current information on Allegheny woodrat research and monitoring.

The goal of this report is to provide information to the Shawnee National Forest and Hoosier National Forest regarding conservation of the eastern woodrat and Allegheny woodrat. Given that the Allegheny woodrat has only been recognized as a distinct species since the early 1990s, very little has been published exclusively about *N. magister*. Early natural history accounts indicate that the Allegheny and eastern woodrats have similar life histories. Throughout this conservation assessment the eastern woodrat will be discussed first and then any differences regarding the Allegheny woodrat will be noted.

NOMENCLATURE AND TAXONOMY

Eastern woodrat

Common Names. Eastern woodrat, wood rat, pack rat, trade rat, Florida wood rat, bush rat, brush rat, cave rat, mountain rat

Scientific Name. *Neotoma floridana*

Subspecies. *N. f. attwateri* (Mearns 1897), *N. f. baileyi* (Merriam 1894), *N. f. campestris* (Allen 1894), *N. f. floridana* (Ord 1818), *N. f. haematoreia* (Howell 1934), *N. f. illinoensis* (Howell 1910), *N. f. rubida* (Bangs 1898), and *N. f. smalli* (Sherman 1955). Hayes (1990) recommends that *N. f. haematoreia* be subsumed under *N. f. floridana.*

The eastern woodrat was collected and described by Ord (1818) from a location near the St. Johns River, Florida. According to Wilson and Reeder (1993), the genus *Neotoma* contains 20 species; 10 species living within the United States and 11 species endemic from Mexico south to Nicaragua.

Allegheny woodrat

Common Names. Allegheny woodrat, Pennsylvania wood rat, Allegheny cliff rat, Allegheny cave rat, mountain rat, wood rat, brush rat, trade rat, pack rat

Scientific Name. *Neotoma magister*, formerly *Neotoma pennsylvanica*
Skull fragments of *N. magister* were collected by Baird (1858) near Carlisle, Cumberland County, Pennsylvania. Stone (1893) described woodrats collected near the top of South Mountain, Cumberland County, Pennsylvania. At the time it was believed that these were a different species, the Pennsylvania woodrat (*Neotoma pennsylvanica*), but Poole (1940b) reported that they were conspecific.

Since the 1950s, the Allegheny woodrat has been considered a subspecies of *N. floridana* (Schwartz and Odum 1957). Investigations of genetic and morphologic characteristics (Hayes and Harrison 1992; Hayes and Richmond 1993) and mitochondrial DNA cytochrome b gene

sequences (Edwards and Bradley 2001) support the recognition of *N. magister* as a distinct taxon.

DESCRIPTION OF SPECIES

Eastern woodrat

The eastern woodrat is a member of the order Rodentia and the family Muridae. In appearance it looks like a large white-footed mouse. Body measurements are: total length 305-450 mm, tail length 130-180 mm, hind foot length 35-42 mm, and ear length 24-29 mm (Rainey 1956). They have 4 clawed digits and a rudimentary thumb on the forelimbs and 5 clawed digits on the hind limbs. Woodrats possess long, curving vibrissae, large naked ears, and prominent eyes that allow nocturnal activity. Females have 2 pairs of inguinal mammae (Finley 1958). In Illinois the average adult weight of 68 males and 77 females (including pregnant individuals) was 284 g and 250 g. Maximum recorded weights were 393 g for a male and 346 g for a female (Monty 1997).

Pelage. The sides and dorsal surface of adult eastern woodrats are gray-brown to bright cinnamon-orange with black-tipped hairs. The ventral surface of adults is white or creamy white. Juveniles are gray with a white ventral surface. The feet are white in all age groups. The tail is almost as long as the body, has short hairs, and is bicolored. It is dusky-gray above and white below. Southern populations may have a unicolor tail (Schwartz and Odum 1957). A brown stain on the mid-ventral pelage results from secretions of a ventral abdominal gland which is present in both sexes but increases in size in adult males during the breeding season. This gland is believed to play a role in scent communication (Poole 1940a) and mother-litter recognition (Clarke 1973).

Skull and Dentition. The dental formula for *N. floridana* is 1/1, 0/0, 0/0, 3/3 = 16. Molars are moderately high crowned and prismatic (Hoffmeister 1989). Greatest length of the skull ranged from 49.3 to 50.3 mm for 131 skulls representing 5 subspecies (Schwartz and Odum 1957). In the past, the presence of a forked anterior palatal spine was used to distinguish *N. floridana* from adjacent species of *Neotoma* (Wiley 1980). With the return of *N. magister* to the species level, a reliable skull characteristic is necessary to distinguish between *N. floridana* and the Allegheny woodrat. The maxillovomerine notch is present in *N. magister* but not in *N. floridana*. The forked anterior palatal spine is less reliable than the maxillovomerine notch because only 71% of 386 *N. floridana* skulls examined had a notched or forked anterior palatal spine (Hayes and Richmond 1993).

Allegheny woodrat

Allegheny woodrats are larger than eastern woodrats. In Indiana, body measurements are: total length 348-431 mm, tail length 141-191 mm, and hind foot length 37-46 mm. The average weight of 13 males was 324.5 g and for 17 females was 293.2 g (Mumford and Whitaker 1982).

Pelage. *N. magister* is grayer than *N. floridana* (Howell 1921) and has a distinctly bicolored tail (Stone 1893). The feet and ventral surface are white. During the summer adults have a strip of fur 130 mm long by 5-7 mm wide worn away down the midline where the ventral abdominal gland is located. Secretions from the gland cause fur discoloration as the ventral surface is rubbed against rocks and the ground (Poole 1940a). This scent marking serves in communication of the location of individuals (Kinsey 1976; Poole 1940a).

Skull and Dentition. The average greatest skull length was 53.5 mm (range=48.6-58.3) for 73 individuals collected across the species range (Schwartz and Odum 1957). A maxillovomerine notch is present (Hayes and Richmond 1993). According to Stone (1893) the skull is proportionally longer and narrower with heavier teeth than in the eastern woodrat.

LIFE HISTORY

Eastern woodrat

Molts. Finley (1958) described the molt cycle of woodrats as involving 2 or 3 molts during the first year; thereafter, molts into winter pelage occur annually. Winter pelage is gray-brown; worn fur is brown to rusty brown (Goldman 1910). The pattern of molting is: juvenile pelage, postjuvenile molt, subadult pelage, second molt, first autumn pelage, third molt, first winter pelage, annual molt. The first molt takes place at 5-6 weeks of age and begins on the abdomen, chest and throat, and then progresses dorsally (Rainey 1956). The annual molt may be delayed 1-3 months in females until the breeding season ends. Southern populations may not exhibit well synchronized molting cycles, but the annual molt usually occurs during June-October (Birney 1973). In Illinois, 21 adult woodrats were observed molting from February to June in 1994-1996 (Monty, personal observation), possibly exhibiting what Birney (1973) described as a "vernal molt" to maintain the pelage.

Body Weight. Adult female woodrats vary in weight throughout much of the year because of pregnancy. A sharp decline in weight may indicate parturition. Rainey (1956) noted that adult male woodrats tend to reach maximum weight in February and March at the beginning of the breeding season and then decrease to their annual minimum in May. Their weight recovers in June, but declines again in July during hot weather. In September and October weight declines because of increased food collecting activity. Weight increases in late fall and winter until the maximum is again reached.

Age Determination. Rainey (1956) classified eastern woodrats into 3 age groups based on pelage color, weight, reproductive condition, and time of year when first captured. Juvenile woodrats had soft gray fur, had not completed their first molt, and were usually less than 150 g. The pelage of subadults was not as bright as adults and body weight was usually less than 250 g for males and 200 g for females. Woodrats were classified as adults at the first signs of sexual maturity. If an individual was captured outside of the breeding season the adult status was determined based on size, pelage, and body weight. Hamilton (1953) documented the pattern of tooth eruption and skull measurements in known age juveniles. Birney (1973) classified 8 age groups based on the degree of eruption of the upper molars and their wear pattern. In adult *N. floridana*, the proximal portion of the baculum is more triangular shaped laterally than in the young (Burt and Barkalow 1942). In most other species of woodrats the baculum of immatures is a miniature of the adult's.

Anatomy. Rodents have a duplex uterus consisting of 2 uteri, 2 cervixes, and a single vagina (Feldhamer et al. 1999). Uterine length reported for 3 species of *Neotoma* ranges from 30 to 43 mm (Howell 1926). During sexual inactivity the vagina is closed, the nipples are small, and hair covers the abdomen (Rainey 1956). Adult male *Neotoma* have paired testes that descend into the scrotum during the breeding season (Howell 1926). The baculum of eastern woodrats has a broad proximal end with upturned lateral projections, resulting in a U-shaped cross section. From the proximal end, the baculum gradually narrows to a rounded shaft (Burt and Barkalow 1942).

Breeding. Duration of the breeding season varies geographically. Some years during the mid 1990s, individuals in Illinois appeared to be in reproductive condition during all months (Monty 1997; Wagle 1996). Woodrats in Florida and southern Georgia appear to breed throughout the year (Hamilton 1953; Harper 1927; Pearson 1952). Breeding occurs from March through October in Oklahoma (Goertz 1970) and from February through August in Kansas (Rainey 1956). Goertz (1970) captured males with fully scrotal testes 15-40 mm long from April to November.

Eastern woodrats are polyestrus with estrous cycles usually lasting 4-6 days (range 3-8) (Asdell 1964). During estrus the vagina is perforate, the clitoris is swollen, and the uteri and ovaries enlarge (Rainey 1956). Females reenter estrus soon after parturition. In the laboratory, Pearson (1952) observed a mating of a female that had a 7-day-old litter.

Females reach sexual maturity at 5-6 months of age or when they weigh about 160 g, unless this time period occurs during winter in northern populations (Fitch and Rainey 1956). Females born in the early spring exhibit reproductive condition during their first autumn but only occasionally produce a litter that season. Birney (1973) captured a subadult in late August that was nursing young less than 2 weeks old. In males and females, sexual maturity usually is reached the year following their birth (Rainey 1956).

Parturition. In the late stages of gestation and during lactation the nipples enlarge and soften and hair loss occurs in the inguinal region (Rainey 1956). Parturition occurs after gestation of 32-38 days, with a mode of 35 days (Birney 1973). If the female is still nursing her previous litter, then delayed implantation may lengthen gestation. Oswald and McClure (1990) reported that a second pregnancy was delayed 3 days when the female was suckling 1 pup, and up to 14 days when suckling 4 pups. The delay allows the energetically expensive late stages of gestation to occur after the previous litter is weaned.

Murphy (1952) observed the birth of the final 3 young in a litter of 4 pups. The female displayed muscular contractions of the abdominal region, held her back in an arched position, and her hind feet were extended forward and parted slightly. Her front feet were held off the floor so the tail and hind legs supported the body. Her head was bent down and eyes were closed. Following each birth, the mother licked the young and consumed the placenta. Each young then attached to a nipple. The litter was born in about 17 minutes.

Newborn. Females in Kansas have 2-4 litters per year (Rainey 1956). Litter size varies from 1 to 6 in Kansas (Kellogg 1915) and Missouri (Schwartz and Schwartz 1959). Two to 7 ($\bar{X}$ □ 3.2) embryos or placental scars were found in 50 females in Oklahoma (Goertz 1970). In Florida, only 1-4 young were born per litter (Worth 1950). Birney (1973) speculated that northern subspecies tend to have larger litter size because they produce fewer litters each year.

Newborn woodrats are altricial, sparsely haired, slate gray on the back, and have a pink muzzle (Rainey 1956). Vibrissae and claws are present. The eyes and pinnae are closed. The young can roll and make uncoordinated movements of the limbs. The upper and lower incisors have erupted, forming a six-sided opening for attachment to the mother's nipple (Hamilton 1953). Females remove nursing young by turning in circles and pushing with the fore feet and nose. Measurements of 21 neonates were: total length 87-96 mm, length of tail 24-27 mm, length of

hind foot 13.5-14.8 mm, weight 11.8-14.1 g (Hamilton 1953). At 9 days of age the ears begin to open and the entire dorsum is furred. Around 15 days the eyes open, the young are well-furred and can run (Rainey 1956). By 20 days of age, solid food can be eaten. Hamilton (1953) assumed that in the wild the young would be weaned when 1 month old, although they will nurse longer in captivity. By 70 days of age the young may leave the nest permanently. Fitch and Rainey (1956) found that woodrats increase in weight about 1.5 g per day until 2 months of age or until they reach 100 g. While 100-149 g, they increased 0.71-0.92 g/day and when greater than 150 g they increased 0.68-0.83 g/day. Adult body weight is reached in about 8 months (Rainey 1956).

Activity. Woodrats become active about 30 minutes before complete darkness and remain active until 30 minutes before sunrise (Wiley 1971). Most activity occurs between 2030 and 2230, and is highest on nights of new or quarter moon phases and lowest on nights of full moon. Murphy (1952) found woodrat activity decreased during extremely cold or rainy weather, although Rainey (1956) stated that woodrats are more active on dark and rainy nights compared to clear nights.

Movements. Pearson (1952) reported that in Florida the mean maximum distance between points of recapture was 54 m, with an extreme of 165 m. Eastern woodrats may tend to make shorter movements in more homogeneous forest habitats because resources are more concentrated (Wiley 1971). In grassland with rock outcrop habitat, such as the western portion of the species range, eastern woodrats may travel greater distances to locate sufficient food, shelter, and mates. Fitch and Rainey (1956) recorded a mean maximum distance of 105 m for 27 adult males and 44 m for 39 subadult and adult females. Maximum distances moved were 329 m for males and 198 m for females. Adult males in reproductive condition moved the greatest distance. Wiley (1971) reported a male that moved 302 m in 4.5 hr. From livetrapping data, Fitch and Rainey (1956) estimated that woodrats usually forage within 23 m of their house.

Food Habits. Woodrats are food generalists that consume primarily mast and herbaceous materials. Individuals that live near agricultural fields collected corn, wheat, and sorghum (Murphy 1952, Rainey 1956) but did not significantly damage the crop. Remains of invertebrates have been found in stomach contents: beetles (Pearson 1952), cicada (Rainey 1956), grasshopper, scorpion, and snail shell (Murphy 1952). Diet varies among habitats and within populations. Each individual collects food within several meters of the house, which results in variation of diet because of availability.

Analysis of woodrat fecal pellets in Illinois revealed a diet of 61-67% mast, such as acorns (*Quercus* spp.) and hickory (*Carya* spp.) nuts, throughout the year. The remaining portion of the diet consists of Virginia creeper (*Parthenocissus quinquefolia*), sedge (*Carex* sp.), hickory nut leaves, and the fruit and leaves of spicebush (*Lindera benzoin*) (Wagle and Feldhamer 1997). Little mast was available on the ground during spring and summer which indicated that the source was caches. Stored mast was rationed to ensure availability throughout the year.

Rainey (1956) believed that quantity of food and availability of house sites were more important limiting factors than the presence specific food plants in Kansas. Murphy (1952) found grass in the diet during early summer in Oklahoma. During the rest of the year acorns; the bark, fruit, and seeds of sumac (*Rhus* spp.); fruit of poison ivy (*Rhus radicans*) and dogwood (*Cornus* spp.); and the seeds of redbud (*Cercis canadensis*) and Kentucky coffee tree (*Gymnocladus dioica*) were

consumed. Pearson (1952) found that captive *N. floridana* ate 91% of herbaceous plants, 57% of shrubs, and 37% of tree species presented.

Nutrient content of plant parts varies seasonally, and after caching by woodrats (Post 1992). To assess the value of available foods, woodrats are able to detect differences in nutrient concentrations (Post 1993). Captive individuals consumed more standard diet food than foods reduced in protein, lipids, and energy.

Eastern woodrats seem able to obtain sufficient water from dew, rain, vegetation, and metabolic processes so that open water is not necessary (Murphy 1952). Woodrats are able to survive in hot, arid environments by consuming succulent vegetation, exhibiting nocturnal activity, and remaining in the house for protection from daytime heat (Lee 1963). Laboratory experiments indicate that if vegetation is not provided, woodrats will drink water using a lapping motion (Murphy 1952).

Aggressive Behavior. Eastern woodrats are solitary animals (Layne 1958; Murphy 1952) and both sexes are highly antagonistic toward other individuals. Rainey (1956) observed 2 adult males placed in the same cage. They approached, touched noses, and then began fighting. Both reared up on the hind legs and bit while lashing with the front feet. The vibrissae move rapidly and the tail is flicked from side to side. A captive male acted aggressively toward a female through a partition and later forced entry into her pen and killed her.

Eastern woodrats are territorial and will defend their house and possibly the surrounding area (Fitch and Rainey 1956). Adults are dominant over subadults and will chase them away from food sources (Wiley 1971).

Escape Behavior. Adults learn the available escape routes from the house so they can respond quickly when in danger. If the house is located at the base of a tree, the woodrat will climb part way up, assess the situation, and may proceed high into the branches. Nursing young are dragged from dangerous situations while clinging to the mother's nipples. If a pup becomes detached the mother may pick it up and carry it in her mouth (Rainey 1956).

House Construction. Eastern woodrats construct 1 or more houses (also called dens) to protect an inner nest and food caches, to moderate temperature fluctuations, to provide shelter from precipitation, and to provide protection from predators. Depending on the available habitat, houses may be built in diverse locations. Habitat in Illinois with rough, rocky terrain was preferred over flat areas due to the prevalence of ledges and caves that provide cover for houses (Layne 1958). When located in crevices, houses may appear as sticks and rubbish filling gaps between rocks. In Kansas, woodrats build at the base of trees in forests or osage orange (*Maclura pomifera*) hedges, in thickets, in hilltop limestone outcrops, inside standing hollow trees, under root tangles along gullies, and in abandoned buildings (Fitch and Rainey 1956). Eastern woodrats may live among brush piles and refuse heaps in Texas (Schmidly 1983) and Missouri (Monty, personal observation). Houses have been observed up to 8 m above ground among tree branches or vines (Lowery 1974). In swamps, houses are built at the base of trees on high ground (Hamilton 1953). In Colorado, houses are often built in the branches of tree cactus (*Opuntia* spp.) (Finley 1958). Subterranean chambers either naturally occurring (Pearson 1952), dug by another species, or dug by the woodrat (Finley 1958) may be used as house sites.

Houses built away from rocks often exhibit a dome or pyramid shape (Fitch and Rainey 1956) typically 0.5–1 m in diameter by >1 m high (Schwartz and Schwartz 1959). Larger woodrats usually live in larger houses (Horne et al. 1998). Some houses reach large dimensions as they are used over many generations: Neal (1967) reported a house 2 m high with a 1 m diameter, and Murphy (1952) observed a linear house built along a fallen tree that was 4 m long by 2 m wide by 1 m high. Houses are built with available materials: twigs, plant stems (Lowery 1974), bark, leaves, stones (Murphy 1952), and cactus joints (Finley 1958). Individual items are usually picked up in the mouth and carried to the site. Larger items may be dragged (Svihla and Svihla 1933). Middens are collections of plant materials, fecal pellets, pollen, bones, and remains of invertebrates within or outside of the house. Over time a midden may become embedded in crystallized urine (amberat). The materials may be preserved for thousands of years if located in a dry, protected environment (Betancourt et al. 1990; Wells 1976).

One to 3 spherical or cup-shaped nests are built within the house either above or below ground (Finley 1958). Nests are up to 20 cm in diameter and may be built of shredded bark, leaves, grass (Schwartz and Schwartz 1959), yucca (*Yucca* spp.) fibers, or feathers (Finley 1958). Houses built outside of caves tend to have more than 1 entrance leading to the nest, providing multiple escape routes in times of danger (Murphy 1952).

Caching. Woodrats have earned the nickname pack rats because of their tendency to collect not only food and building materials but also any other materials that happen to be present for placement on the house: bones, dry dung, broken glass, cans, empty shotgun shells, bits of paper (Rainey 1956), corn cobs, and rusty nails (Nawrot and Klimstra 1976). In the caches of females, Horne et al. (1998) found bones possibly indicating an increased mineral requirement for reproduction. Eastern woodrats begin caching food in September or October but do not cache much during the spring or summer (Rainey 1956). Among captive woodrats, young model their caching choices after their mother's caching patterns, which should lead to collection of appropriate foods (Post et al. 1998). Woodrats discriminate between foods based on perishability and then decide whether to consume or cache accordingly (Post and Reichman 1991; Reichman 1988). Adults and young cache dry foods but consume moist foods (Post et al. 1998; Reichman 1988). In Kansas, larger individuals had more days of energy stored in the cache than smaller individuals (range 25-271 days). When smaller individuals deplete their cache, they must forage outside the house and become more vulnerable to predation. The mean energy content of caches was 3,682 kcal (SE = 53 kcal) in October and 2,369 kcal (SE = 22 kcal) in December (Post et al. 1993).

Other Behavior. Woodrats groom their pelage by licking and separating the fur with the front feet. Woodrat skin is relatively loose. Areas that are not easily groomed are pulled to the mouth. The face is cleaned by licking the forefeet and rubbing them in a circular motion. Dust bathing areas have been found near houses in Kansas (Rainey 1956).

Defecation and urination are usually restricted to latrine sites away from the house. Scat piles 450 mm by 250 mm and up to 50 mm deep have been recorded (Schwartz and Schwartz 1959). Urination sites 150-200 mm in diameter are indicated by a dark stain on rocks.

Allegheny woodrat

Molts. Molting usually progresses evenly so that there is no contrasting pattern between worn and new pelage (Poole 1940a). The winter pelage observed from November to January exhibits a darker and grayer dorsum and more ochraceous sides. The summer pelage is more brown.

Anatomy. Burt and Barkalow (1942) felt that the eastern and Allegheny woodrat bacula were so similar that they were indistinguishable.

Breeding. In Kentucky, Allegheny woodrats give birth from March to possibly October (Thomas 2001). Poole (1940a) reported that in captivity 2-3 litters were born per year between mid-March and early September. Average litter size is 2 (range=1-3). Estimated gestation length is 30-36 days.

Newborn. Neonates weigh about 15 g (Poole 1940a). By 5 days of age they have fine gray hairs and are fully furred by 14 days. By 15 days old the eyes are sensitive to light and begin to open by day 19. As early as day 17, young begin to eat solid food. Pups will nurse until about 1 month of age if allowed.

Activity. Allegheny woodrats are most active 30 minutes after sunset to just before daylight with peak activity around midnight. Activity is reduced during rain and cold weather. During winter, woodrats are difficult to capture because they tend to remain in caves and crevices (Poole 1940a).

Movement. Individuals may move away from the den when searching for food or mates, or during natal dispersal (Poole 1940a). Thomas (2001) reported that an adult male moved 3,615 m from the location of his previous capture 49 days earlier. The movement occurred between November and January. The individual remained at the new site for at least 1 year. The longest movement recorded for a female was 405 m. The longest movement between 2 consecutive days of capture was 638 m by an adult male.

Food Habits. Cudmore (1985) found that the most important foods (by percent volume) in Indiana were tree of heaven (*Ailanthus altissima*), persimmon (*Diospyros virginiana*), Virginia creeper, acorns, Japanese honeysuckle (*Lonicera japonica*), and red cedar (*Juniperus virginiana*). During years with reduced mast availability, green vegetation and fungi are used more frequently in West Virginia (Castleberry 2000). In the past, the American chestnut (*Castanea dentata*) provided a source of hard mast for woodrats (Howell 1921; Poole 1940a). Loss of this important food has been suggested as a contributing factor in population declines (Balcom and Yahner 1996). Neal (1967) reported that consecutive years with reduced mast could have negative effects on woodrat populations. Gnawed bones found in caches provide minerals and sharpen teeth. Some individuals will drink water in captivity (Poole 1940a).

Aggressive Behavior. Kinsey (1977) observed territorial behavior in a confined population of Allegheny woodrats. Females defended a territory during spring and summer, whereas males were aggressive and territorial in fall and winter. Woodrats held in groups were highly aggressive with an alpha individual killing or wounding others (Kinsey 1976).

Nest Construction. Allegheny woodrats usually do not cover their nest with a stick house unlike eastern woodrats. Globular nests are built in deep crevices, fissures, or caves out of red cedar

shavings, grasses (Mumford and Whitaker 1982) or the shredded bast fibers of hemlock (*Tsuga canadensis*), wild grape (*Vitis* spp.) (Poole 1940a), basswood (*Tilia heterophylla*), or American chestnut (Newcombe 1930). Debris piles (middens) of sticks, bark, bones, feathers, dung, and trash may be built to protect the openings of caves or fissures (Newcome 1930; Poole 1940a; Whitaker and Hamilton 1998). Middens containing collected food are common in Indiana (Whitaker and Hamilton 1998). Mumford and Whitaker (1982) found a nest within a midden at two locations in Indiana. In areas without caves in West Virginia, Allegheny woodrats build stick houses over nests (Poole 1940a).

Caching. Allegheny woodrats cache raccoon feces (LoGiudice 2000; McGowan 1993a). Seeds within the feces or the feces themselves may be considered a food source (LoGiudice 2000). Raccoon feces are allowed to dry before collection which facilitates transportation.

Other Behavior. Woodrat latrine sites typically are found in open places or under overhanging rocks (Poole 1940a).

Figure 2. Distribution of current and historic populations of eastern woodrats in southern Illinois (adapted from Nawrot 1974).

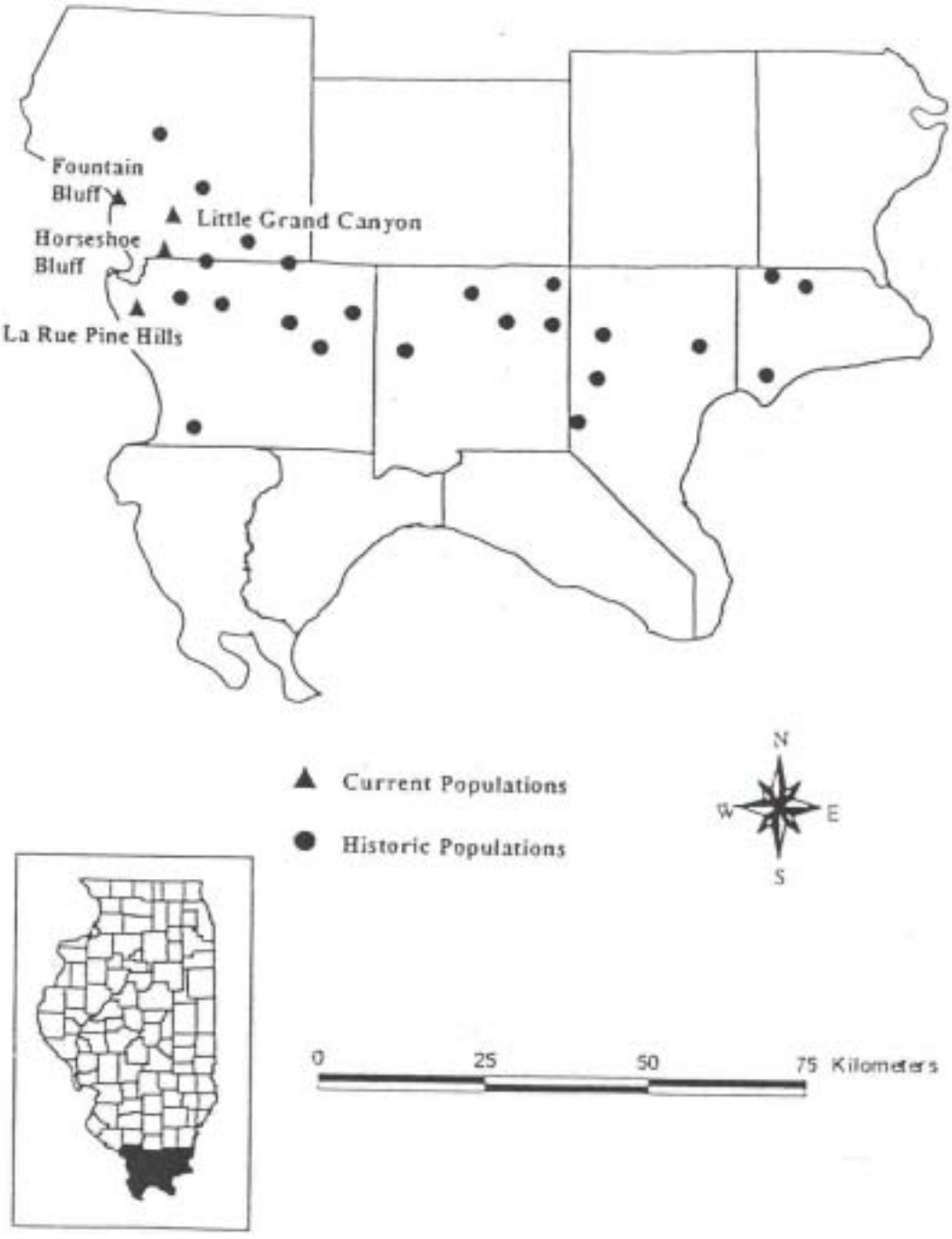
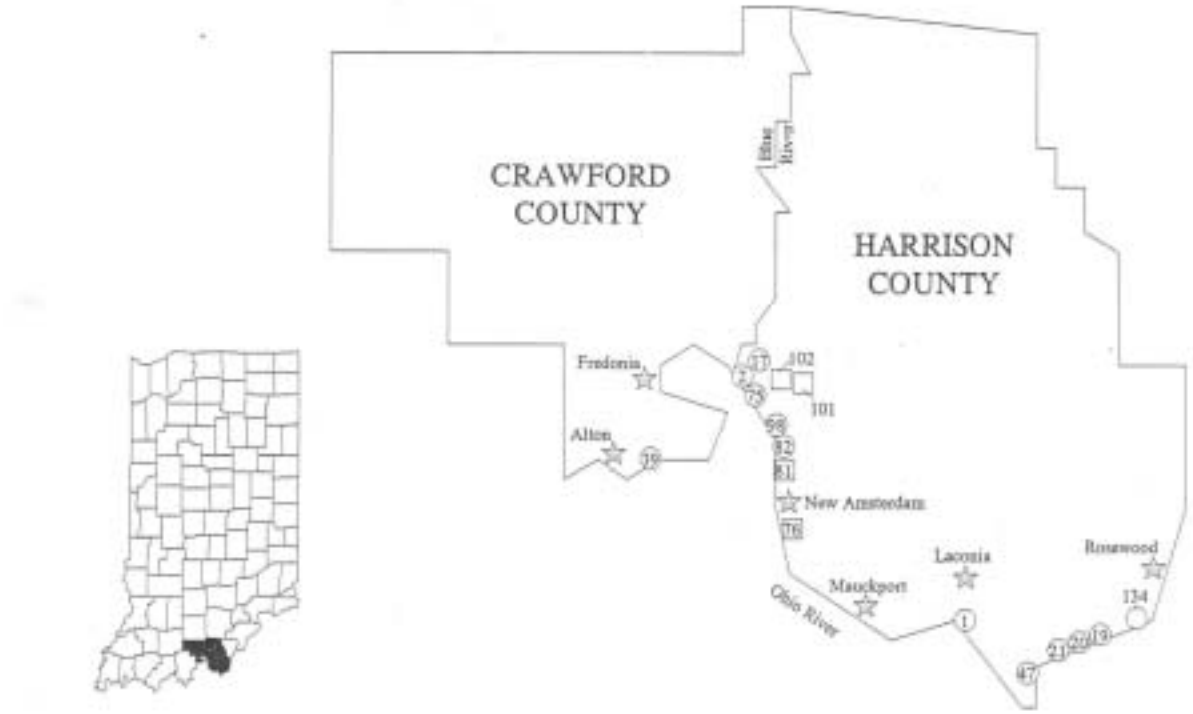


Figure 3. Distribution of survey sites for Allegheny woodrats in Crawford and Harrison counties, Indiana in 1996. Circles denote sites occupied by woodrats and squares denote sites at which no woodrats were captured (from Johnson et al. 1997).



HABITAT

Eastern woodrat

Eastern woodrats live in a variety of habitats throughout their range. They occur in upland woods, brushy riparian woods (Goertz 1970), wooded bottomland (Neal 1967), swamps (Hamilton 1953), and rocky bluffs with caves and crevices (Nawrot and Klimstra 1976). In grassland habitat, woodrats are associated with hedgerows or rock outcrops. Rainey (1956) believed the species' range was limited in Kansas by the lack of overhead cover and outcroppings with suitable crevices. In Colorado, grassland alone was insufficient for eastern woodrats (Finley 1958). If no trees were available, woodrats were associated with shrubs, yucca, or tree cactus which were used for shelter and food. A structure of sticks or other materials, referred to as a house or den, is built for shelter.

Allegheny woodrat

Allegheny woodrats usually inhabit crevices in rocky bluffs, talus slopes, and caves (Howell 1921; Poole 1940a). The propensity to live in protective rock shelters may explain why they may not cover the nest proper with a stick house, as would an eastern woodrat. Howell (1921) and Newcome (1930) stated that Allegheny woodrats never live in lowland swamp.
Cudmore (1985) found that occupied sites in Indiana had dry caves or extensive limestone cliffs that were south-facing. Occupied sites in Pennsylvania were more often south-facing than

historically occupied sites (Balcom and Yahner 1996). Historically occupied sites have experienced an increase in residential and agricultural use compared to occupied sites. The amount of coniferous forest also may influence persistence of woodrat populations. Historical sites had a higher percent of coniferous cover than occupied sites.

DISTRIBUTION AND ABUNDANCE

Eastern woodrat

The eastern woodrat occurs across the southeastern United States south of the Tennessee River to central Florida. The species range continues west to central Texas, Oklahoma, and Colorado. The northern portion of the range includes Kansas, central Missouri, southern Illinois, and western Tennessee. There are no known extant populations in western Kentucky, although this area is usually included in the species range (Steven Thomas, pers. comm.). Disjunct populations occur in Nebraska and on Key Largo, Florida (figure 1).

In Illinois, it is likely that woodrats historically occurred as far north as the bluffs near East St. Louis during warmer climatic conditions. Skeletal remains of a minimum of 535 eastern woodrats (dating from about 4,000-1,000 B. C.) were recovered from Meyer Cave, Monroe County (Parmalee 1967). Meyer Cave is about 105 km northwest of extant populations in Jackson County and Union County (figure 2). Nawrot and Klimstra (1976) estimated that populations in the eastern part of the Shawnee National Forest were extirpated about 50-75 years ago. Recent distribution and abundance in Illinois are detailed in table 1.

Allegheny woodrat

The Allegheny woodrat historically ranged from southern New York, western Connecticut, and northern New Jersey south through much of Pennsylvania, western Maryland, Virginia, North Carolina, and southern Ohio and Indiana. The Tennessee River limits the southern extent of the range (figure 1). Poole (1940b) noted that woodrats were once more widely distributed in Pennsylvania based on skeletal remains present in many locations lacking extant populations. Population declines during the last 20 years across the northeastern portion of the range resulted in the extirpation of Allegheny woodrats in New York and Connecticut. New Jersey and Ohio each support only 1 known population (Woodrat Recovery Group 1993).

Recent woodrat fossils have been found in several counties in the karst region of Indiana as far north as Owen County (Richards 1972). As recently as 1973, woodrats were present in Big Wyandotte Cave, Crawford County (Mumford and Whitaker 1982). Surveys conducted between 1991 and 1996 (table 2) resulted in the capture of 95-123 individuals per year from 11-12 sites in Harrison and Crawford counties (figure 3). Mean capture rate was about 11 woodrats/km of linear bluff (Johnson et al. 1997; Johnson and Madej 1993; Johnson and Marmer 1995). The number of woodrats in Indiana has declined over the past 20 years; Cudmore (1985) captured 115 individuals at 6 sites in Harrison and Crawford counties. At that time, population densities averaged 27.5/km of cliff. Statewide estimates considering all suitable habitat ranged from 781-1,206 depending on calculation technique.

STATUS

Eastern woodrat

Eastern woodrats have been assigned a global rank of G5 indicating that the species is secure. They are listed as endangered, threatened, or of special concern in only 5 of the 17 states in which they occur (table 3). State status designations may not be current because very little woodrat research is being conducted in areas where woodrats are presumed to be common. The eastern woodrat is state-endangered in Illinois. It is notable that the states with documented population declines are on the periphery of the range.

Allegheny woodrat

Allegheny woodrats have been assigned the global rank of G3/G4 indicating that the species is vulnerable to apparently secure. They are state-listed at various levels or are at least on a watch list in 10 of the 11 states in which they occur (table 4). The Allegheny woodrat is state-endangered in Indiana. The species was proposed as a candidate for federal listing under the Endangered Species Act but the petition was denied because populations in the southern portion of the range appear to be stable (Beans 1992).

POPULATION BIOLOGY AND VIABILITY

Eastern woodrat

Sex Ratio. The neonatal sex ratio is 1:1 (Birney 1973). Monty (1997) captured 41.7% males and 58.3% females among 283 individuals (all ages) in Illinois. Goertz (1970) reported a nearly 1:1 ratio across all age groups in 281 eastern woodrats captured in Oklahoma. Rainey (1956) captured 55.3% males and 44.7% females among 105 woodrats in Kansas.

Home Range and Population Density. Goertz (1970) estimated the average home range was 0.26 ha for males and 0.17 ha for females captured 5-24 times. Tate (1970) reported an average home range for 8 woodrats was 0.03 ha to 0.2 ha depending on the calculation method. Subadults have larger home ranges than adults. Adult males have larger home ranges than adult females because they tend to make longer movements in search of mates.

Population density estimates vary widely by location and census method. In Louisiana, Neal (1967) estimated woodrat density using the strip census method. Houses that appeared active were counted and assumed to house 1 woodrat. This resulted in estimates of 0.82 woodrats per ha in 1965 and 0.2/ha in 1966 following a population decline. Fitch and Rainey (1956) used trapping data to estimate a density of about 4.25/ha after a decline. Humphrey (1988) used capture histories and probability models from computer program CAPTURE to estimate a mean density of 7.6/ha on Key Largo. He concluded that past estimates from Key Largo were unreliable because they measured abundance of sign (houses, latrine sites, burrows) which is not well correlated with population size. The most recent survey of Key Largo woodrats by Frank et al. (1997) found that small sample size and low number of sequential nights trapped prohibited the use of program CAPTURE. An enumeration estimation technique yielded a mean density of 0.9 woodrats/ha.

Survival. In an Illinois upland woods and bluff habitat, 23% of woodrats remained for at least 1 year in a 3-year study (Monty 1997). About 5% of woodrats were recaptured after 1 year in Oklahoma during a 2-year study in prairie, savanna-edge, upland woods, and brushy riparian woods (Goertz 1970). Of 27 individuals caught as juveniles in Kansas, only 6 survived to adult size and only 3 survived long enough to reproduce (Rainey 1956). Goertz (1970) reported that males disappeared from the study area sooner than females possibly because of exposure to predation while traveling longer distances. Woodrats live longer than most other small mammals. Fitch and Rainey (1956) report that an adult male was recaptured 827 days later. An adult female was captured throughout a 1,089-day period (Monty 1997). In captivity, eastern woodrats tend to live about 2 years (Birney 1973) but have lived as long as 4 years (Schwartz and Schwartz 1959).

Allegheny woodrat

Sex Ratio. In Indiana, between 1991 and 1996, 43.6% of woodrats captured were males and 56.4% were females among 353 individuals (Johnson and Madej 1993; Johnson and Marmer 1995; Johnson et al. 1997; Madej and Johnson 1993). In Kentucky, between May 1997 and September 2001, among 214 individuals captured 55.1% were males and 44.9% were females (Thomas 2001).

Home Range and Population Density. Home range was estimated using radiotelemetry for 34 woodrats in West Virginia (Castleberry 2001). Mean home range for 18 males was 6.5 $\pm$ 1.8 ha and for 16 females was 2.2 $\pm$ 0.3 ha. These home range estimates are much larger than those reported for eastern woodrats possibly because the telemetry was conducted in spring and summer when individuals forage widely and travel seeking mates.
Population density for 6 sites in Indiana averaged 27.5/km of cliff habitat during the early 1980s (Cudmore 1985). During the 1990s density averaged about 11 individuals/km at 12 Indiana sites (Johnson et al. 1997; Johnson and Madej 1993; Johnson and Marmer 1995).

Survival. Individuals may live over 4 years in the wild (Thomas 2001) or in captivity (Poole 1940a).

POTENTIAL THREATS AND MONITORING

Eastern woodrat

Predation. Rainey (1956) believed that predators could keep woodrat numbers suppressed at low population levels because woodrats have relatively low reproductive potential. Possible woodrat predators include: spotted skunk (*Spilogale putorius*), long-tailed weasel (*Mustela frenata*), black rat snake (*Elaphe obsoleta*), great horned owl (*Bubo virginianus*), timber rattlesnake (*Crotalus horridus*) (Fitch and Rainey 1956), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana)*, cottonmouth (*Agkistrodon piscivorous*), and copperhead (*A. contortrix*) (Crim 1961). Juveniles are highly susceptible to predation by snakes while in the den before weaning.

Weather. Nawrot and Klimstra (1976) attributed the decline in Illinois woodrat populations to severe winters during 1912 and 1918, in conjunction with some formerly occupied sites being in marginal habitat. Fitch and Rainey (1956) attributed the decline of woodrat populations in Kansas to unusually cold winters with heavy accumulations of snow and ice during 2 consecutive years. Extreme cold in March 1948 could have caused the death of the season's first

litter. In January 1949, there was ice cover for at least 21 days. Lack of available food could have led to starvation of some individuals.

Gypsy Moth. Neal (1967) concluded that a decline in woodrat population density in 1966 in the lower Mississippi River Basin was caused by poor acorn crops during 1964-1965 caused by gypsy moth (*Lymantria dispar*) invasion.

Raccoon Roundworm. Infection with *Baylisascaris procyonis*, an intestinal roundworm of raccoons, has not been reported in eastern woodrats, although it is a mortality factor in Allegheny woodrats (Johnson et al. 1997; LoGiudice 2000; McGowan 1993a). Little information exists on the prevalence of *B. procyonis* in raccoons living in the vicinity of *N. floridana* populations. Birch et al. (1994) found only a 5% occurrence of *B. procyonis* among raccoons sampled in southern Illinois. Prevalence of *B. procyonis* seems to decrease in southern latitudes (Harkema and Miller 1964) which may reduce the threat to eastern woodrats.

Allegheny woodrat

Four principal causes for population declines have been suggested: increased predation by great horned owls, changes in the landscape such as forest fragmentation and changing forest composition (Balcom and Yahner 1996), reduced availability of acorns (McManus and McIntyre 1981) and American chestnuts (Woods and Shanks 1959), and infection with *Baylisascaris procyonis*.

Many small mammals and birds forgage for seeds at the defecation sites (latrines) of raccoons (Page et al. 1999). Woodrats are an intermediate host for *B. procyonis* and may ingest the nematode eggs while collecting dried raccoon feces (LoGiudice 2000; McGowan 1993a). *B. procyonis* eggs are not harmful until embryonated, which occurs about 30 days after deposition (Kazacos and Boyce 1989). Infection leads to lethargy, loss of muscle control, and eventual death (Kazacos and Boyce 1989; Kazacos et al. 1981). *B. procyonis* is a mortality factor in woodrats in Indiana (Johnson et al. 1997), New York (McGowan 1993a), New Jersey, and Pennsylvania (LoGiudice 2000). The *B. procyonis* infection rate of raccoons in the midwest and northeastern United States is 68-82% (Kazacos and Boyce 1989). Therefore, large quantities of infected feces are present in the environment. Eggs remain viable for at least 5-6 years (Kazacos and Boyce 1989). Forty-nine percent of raccoon latrines were located on logs in Tippecanoe County, Indiana (Page et al. 1998). Woodrats use logs as pathways (Monty, personal observation) which results in much contact with infected latrines either accidentally or during caching.

In 1995, raccoon latrine sites were sampled in Indiana to determine levels of *B. procyonis* at sites occupied by woodrats (Scott Johnson, pers. comm.). Periodic monitoring of *B. procyonis* using a standardized protocol could provide valuable information regarding trends in parasite levels (McGowan 1993b). Ten years ago, Lehman (1993) reported that Indiana raccoon populations were at record high levels.

PRESENT OR THREATENED RISKS TO HABITAT OR RANGE

Eastern woodrat

Known populations of eastern woodrats in Illinois live on Forest Service property which limits the risk of development. Timber harvesting is the most likely risk at these sites. Removal of mature mast producers would reduce local food resources. Woodrats would have to travel farther to collect food and the additional exposure might lead to higher predation mortality. Undisturbed forested land must remain nearby to provide sufficient food resources.
Fragmentation of forest cover creates islands of suitable woodrat habitat. Populations in isolated habitat may be extirpated because of demographic, genetic, or environmental stochastic factors (Soulé 1987). Such areas are unlikely to naturally repopulate due to human-influenced changes in landscapes including agricultural use, housing developments, and roads.

Allegheny woodrat

Allegheny woodrats in Indiana recently have inhabited 7 sites (Johnson et al. 1997) on state-owned property (mainly Harrison-Crawford State Forest). Timber harvesting is the most likely risk at these sites. Removal of mature mast producers would reduce local food resources. Woodrats would have to travel farther to collect food and the additional exposure might lead to higher predation mortality. Undisturbed forested land must remain nearby to provide sufficient food resources (Castleberry 2001). Three of the 7 sites on state land are protected within the Deam Nature Preserve. Eight occupied sites are found on private land in Harrison and Crawford counties. Woodrats usually live in rocky areas. As long as there is no direct disturbance or development on the rocks and surrounding forest, suitable habitat should remain. Forest fragmentation between suitable habitats may prevent recolonization of vacant sites.

SUMMARY OF LAND OWNERSHIP AND EXISTING HABITAT PROTECTION

Eastern woodrat

All known populations of eastern woodrats in Illinois live within the Shawnee National Forest (Monty 1997; Monty et al. 1995). The Pine Hills population is further protected within an area designated as a national ecological area. Private land adjacent to the woodrat population at Fountain Bluff, Jackson County, could be purchased to ensure that potential habitat is not destroyed by land owners.

Allegheny woodrat

Allegheny woodrats in Indiana recently have inhabited 7 sites (Johnson et al. 1997) on state-owned property (mainly Harrison-Crawford State Forest). As noted, 3 of the 7 sites on state land are protected within the Deam Nature Preserve. Eight occupied sites occur on private land in Harrison and Crawford counties. In the future, conservation agreements or land purchases could further protect habitat for these populations.

SUMMARY OF EXISTING MANAGEMENT ACTIVITIES

Eastern woodrat

A 5-year study to monitor eastern woodrats in known locations in Illinois will begin in August 2002. This project, a cooperative effort between Illinois Department of Natural Resources, U. S. Forest Service, and Southern Illinois University, will monitor abundance and genetics of extant populations while reintroducing woodrats to several previously occupied sites (see Reintroductions p.15).

Allegheny woodrat

Currently there are no existing management activities for Allegheny woodrats in Indiana. Lack of studies of long-term population dynamics or habitat requirements results in few management plans for woodrats.

PAST AND CURRENT CONSERVATION ACTIVITIES

Habitat protection is the only conservation practice in use for woodrats in Indiana. As noted, recovery efforts for several extirpated populations in Illinois will be initiated in August 2002.

RESEARCH AND MONITORING

Eastern woodrat

Existing Surveys, Monitoring and Research. See table 5

Survey Protocol. The Wagle (1996) and Monty (1997) survey protocols were adapted from the basic monitoring protocol designed and recommended by members of the Allegheny Woodrat Recovery Group. At Pine Hills and Fountain Bluff, 40 live traps were set for 3 consecutive nights every 3 weeks from May to September. From October to April trapping was conducted every 4 weeks. Traps were baited with corn and sunflower seeds and placed near woodrat houses or runways. Polyester fiber fill bedding was placed in traps.

Research Priorities

Monitoring. In many states, eastern woodrats are considered to be relatively common, so that few resources have been invested in population assessments. In regions experiencing population declines, monitoring programs and habitat protection must take place. Periodic monitoring of endangered populations is necessary but livetrapping may pose a threat to captured woodrats. Mortality may result from disturbance by predators, attack on neonates by ants (Stones and Hayward 1968), and accidental trap deaths.

In Illinois, extant woodrat populations need monitoring to gain information regarding population status. Adjacent land with suitable habitat should be visually inspected for woodrat sign and live traps placed to discover additional populations.

Reintroductions. Populations in isolated habitat may be extirpated because of demographic, environmental, or genetic stochastic factors (Soulé 1987). Isolated areas are unlikely to be

naturally repopulated due to anthropogenic factors including agricultural use, housing developments, and roads. Reintroduction of genetically diverse individuals into previously inhabited sites may aid in local recovery projects. For example, Monty (1997) recommended that formerly inhabited sites in southeastern Illinois should be repopulated by translocations of woodrats from southwestern Illinois.

The U. S. Forest Service and the Illinois Department of Natural Resources will conduct a woodrat translocation project (noted above) using individuals from Pine Hills, Union County and sites in Missouri to repopulate areas in the eastern Shawnee National Forest. Food sources utilized by the Pine Hills woodrats, such as hickory and oak mast (Wagle and Feldhamer 1997), should be available at potential sites. Raccoon latrine sites at the reintroduction sites should be monitored for the presence of *Baylisascaris procyonis* eggs. Possible sites for reintroduction are Lusk Creek or Bell Smith Springs, Pope County. Theoretically, translocated individuals should be genetically diverse because the presence of more alleles may allow for adaptation to the new environment (Lacy 1988). Translocations that involve more individuals into excellent habitat tend to be more successful than translocation of fewer individuals into poor habitat (Wolf et al. 1996). Monty (1997) recommended the translocation of about 20 individuals. If juveniles are forced out of the most suitable habitat and then fail to reproduce, relocation of juveniles and subadults to uninhabited sites could be conducted without negatively impacting the Pine Hills population. The sex ratio should be skewed toward females because eastern woodrats are polygynous and do not form pair bonds (Asdell 1964). After the first year, if the effects of removal were negligible, then translocations could be repeated for a few years. The establishment of woodrat populations in the eastern Shawnee could protect the species from extirpation in Illinois.

Raccoon Roundworm. Little information exists on the prevalence of *Baylisascaris procyonis* in raccoons living in the vicinity of *N. floridana* populations. Sites being considered for reintroductions and areas in which woodrats currently live should be monitored for *B. procyonis*.

Habitat. To ensure long-term survival of the species, suitable habitat must remain undeveloped. As development encroaches upon more remote areas, local populations may be adversely affected. Research on the effects of timber harvests near eastern woodrat colonies should be conducted. Removal of mature mast trees would reduce food availability, although brush piles left behind could provide shelter for houses. Investigations that compare the rock cover and food resources available at occupied versus formerly occupied sites may reveal environmental factors that affect population survival (Balcom and Yahner 1996).

Other Research Areas. Researchers face many challenges while collecting basic data. Woodrat behavior is difficult to observe because of their nocturnal activity and use of houses or caves. Photography and direct observation using red light have revealed activity outside of shelters (Finley 1959, Wiley 1971). Mate choice, breeding success, parentage, and genetic diversity studies will be facilitated as genetic techniques are developed and the technology becomes more widely available. Radiotelemetry projects could investigate dispersal patterns of subadults, although cliff habitat makes location of individuals difficult.

Key Largo woodrat. The Key Largo woodrat (*N. floridana smalli*) is listed as endangered by both the Florida Fish and Wildlife Conservation Commission and the U. S. Fish and Wildlife Service. The most recent population assessment was conducted in 1995, 3 years following

Hurricane Andrew (Frank et al. 1997). The resulting density estimates were much lower than estimates from the 1980s and indicated a significant decline in numbers at the southern end of North Key Largo. To protect the remaining tracts of hammock habitat, land has been acquired by state and federal agencies to create preserves for native species. The following management recommendations and research areas have been identified: semi-annual livetrapping for monitoring presence/absence, and long-term population dynamics; determine structural requirements of woodrat habitat, the effects of exotic species, human development, and habitat fragmentation; and investigate the possibility of future habitat restoration efforts. The effect of fire ants (*Solenopsis invicta*) on woodrat survival has not been studied. Livetrapped small mammals may be killed by fire ants, therefore helpless woodrat pups in terrestrial houses could experience increased mortality.

EXISTING SURVEYS, MONITORING AND RESEARCH

See table 2

Survey Protocol. There has been some form of regular monitoring of Allegheny woodrats in Indiana, Kentucky, Maryland, New Jersey, Pennsylvania, and West Virginia (Thomas 2001). In Indiana, 15-60 live traps baited with sliced apple were set for 2 consecutive nights near nests, middens, and latrines and in rock crevices. Trapping was conducted from early July through mid-October on a biennial basis from 1991 through 1996 (Johnson and Madej 1993; Johnson and Marmer 1995; Johnson et al. 1997; Madej and Johnson 1993).

In Kentucky, between May 1997 and September 2001 bimonthly trapping using 40 live traps set for 2 consecutive nights at 3 sites yielded 214 individuals (Thomas 2001). During cold weather, polyester fiber fill bedding and shelled walnuts were placed in traps. Although Monel #1 or #3 ear tags are commonly used to identify individuals (Johnson et al. 1997; Monty 1997), Thomas (2001) found that 23.6% of marked woodrats lost 1 tag or more. Subsequently, ear tattooing was used. At the end of the 5-year period Kentucky will no longer directly monitor Allegheny woodrats. Presence or absence of woodrat sign will be noted during surveys of bat hibernacula.

Research Priorities. Ultimately, the most important research area that must be investigated is the causes of population declines throughout most of the species range and extirpations in New York and Connecticut.

Monitoring. Collection of information on the basic ecology of Allegheny woodrats is necessary. In Indiana, analysis of data from 2 years of bimonthly trapping at Harrison-Crawford State Forest and Tobacco Landing, Harrison County, will indicate long-term population trends. During summer of 2002, research efforts will return to monitoring the other 15-18 historical or currently occupied sites. In the future, Indiana populations could be monitored every 4-5 years rather than biennially because population sizes seem stable over the last 10 years (Johnson et al. 1997). Likewise, the state of Kentucky will no longer monitor Allegheny woodrats with livetrapping because populations appear relatively stable. A long-term monitoring program is being planned at Mammoth Cave National Park (Steven Thomas, pers. com.).

Raccoon Roundworm. Historical sites and currently used habitat should be monitored for raccoon latrine sites and *Baylisascaris procyonis* (McGowan 1993b). An investigation into experimental innoculation of woodrats with varying levels of *B. procyonis* eggs is underway but has not yet been completed (Scott Johnson, pers. comm.). This study may reveal the level of

environmental contamination with *B. procyonis* eggs that should be considered a threat to woodrats. In experimental populations, LoGiudice (2000) found that woodrats in sites with higher levels of *B. procyonis* contamination had lower survival than those in lower contamination sites. LoGiudice (1995) developed and tested a raccoon bait dosed with piperazine, an anthelmintic, for short-term, local control of *B. procyonis*. Periodic worming of resident raccoons might increase survival for small woodrat populations of special concern.

Reintroduction. Reintroduction of Allegheny woodrats into historical sites could occur if the causes of the decline and extirpations are determined and rectified. At this time reintroductions are not being considered in Indiana because the cause of the decline is unknown and several of the inhabited sites are close enough that movement between sites and repopulation of vacant sites can occur naturally (Scott Johnson, pers. com.).

Habitat. Investigations that compare the rocky cover and food resources available at occupied versus historically occupied sites may reveal environmental factors that affect population survival. Cudmore (1985) in Indiana and Balcom and Yahner (1996) in Pennsylvania have begun to address these issues. The type of timber harvest practices used near woodrat populations may affect use of habitat. In West Virginia, timber harvests near woodrat colonies had minimal impact as long as intact forest remained nearby (Castleberry 2001).

Figure 1. Range of the eastern woodrat and Allegheny woodrat (adapted from Hall 1981).

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TABLES

Table 1. Recent distribution and abundance of Eastern woodrats in Illinois.

Year(s)	Location	Individuals Captured	Monthly Minimum Number Known Alive	Citation
1993-1996	Pine Hills , Union County	283	24-64	Monty (1997)
1994-1995	Fountain Bluff, Jackson County	94	8-30	Wagle (1996)
1994-1995	Little Grand Canyon, Jackson County	21	No estimate made	Monty (1997)
1994-1995	Horseshoe Bluff, Jackson County	19	No estimate made	Monty (1997)
1996	Cribs Bend, Jackson County	4	No estimate made	Monty (1997)

Table 2. Existing surveys, monitoring, and research for Allegheny woodrats in Indiana, 1980-2002.

Year(s)	Location	Type of Monitoring	Citation
1980-1983	Perry, Crawford, Harrison, Floyd, Clark, Jefferson counties	Inspect for sign Assess suitability of sites Livetrap 6 sites	Cudmore (1985)
1991-1992	12 sites in Harrison and Crawford counties	Livetrapping	Johnson and Madej (1993)
1993	3 sites in Harrison County	Livetrapping; Assess sites for sign in 6 counties	Madej and Johnson (1993)
1994	11 sites in Harrison and Crawford counties	Livetrapping	Johnson and Marmer (1995)
1996	12 sites in Harrison and Crawford counties	Livetrapping	Johnson et al. (1997)
1998-2002	Harrison-Crawford State Forest and Tobacco Landing	Livetrap bimonthly	Scott Johnson (pers. comm.)

Table 3. Status of the Eastern Woodrat for states within its range according to online websites.

State	Status
Alabama	No Official Status
Arkansas	No Official Status
Colorado	No Official Status
Florida *N. floridana floridana* *N. floridana smallii*	No Official Status Federally Endangered
Georgia	No Official Status
Illinois	Endangered
Kansas	No Official Status
Kentucky	No Official Status
Louisiana	No Official Status
Mississippi	No Official Status
Missouri	No Official Status
Nebraska	No Official Status
North Carolina *N. floridana floridana* *N. floridana haematoreia*	Threatened Species of Concern
Oklahoma	No Official Status
South Carolina	Species of Concern
Tennessee	In Need of Management
Texas	No Official Status

Table 4. Status of the Allegheny Woodrat for states within its range according to online websites.

State	Status
Alabama	Species of Concern
Connecticut	Extirpated
Indiana	Endangered
Kentucky	No Official Status
Maryland	Endangered
New Jersey	Endangered
New York	Extirpated
North Carolina	Special Concern
Ohio	Endangered
Pennsylvania	Threatened
Tennessee	In Need of Management
Virginia	Watch List
West Virginia	Watch List

Table 5. Existing surveys, monitoring, and research for Eastern woodrats in Illinois, 1961-1997.

Year(s)	**Location**	**Type of Monitoring**	**Citation**
1959-1961	Pine Hills, Union County; Fountain Bluff, Horseshoe Bluff, Jackson County	Livetrapping	Crim (1961)
1972-1973	Pine Hills, Union County; Fountain Bluff, Horseshoe Bluff, Jackson County	Livetrapping; Search for formerly occupied sites in the eastern Shawnee Forest	Nawrot (1974)
1980s	Pine Hills, Union County	Nest surveys	West (1986)
1994-1995	Fountain Bluff, Jackson County	Livetrapping	Wagle (1996)
1993-1996	Pine Hills, Union County; Little Grand Canyon, Horseshoe Bluff, and Cripps Bend, Jackson County	Livetrapping, Collected tissue for genetic analyses	Monty (1997)

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REVIEW REQUESTS

Steven C. Thomas (contact information above) has expressed interest in reviewing this document