The Present Distribution and Status of the Eastern Woodrat, *Neotoma floridana*, in Indiana

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Introduction

Although the genus *Neotoma* is best represented in southwestern United States, the eastern woodrat, *Neotoma floridana*, has a rather widespread distribution in both western and eastern United States. The species occurs as far west as Colorado and in the east from extreme southern Illinois, Indiana, Ohio and New York south to Louisiana, Alabama, Georgia and Florida. It is absent along the coast from New Jersey to central South Carolina and Georgia. The presence of *N. floridana* in Indiana was not documented until 1930 (Hickie and Harrison 1930) although there were references to what were probably woodrats as early as 1872 (Cope 1872, Packard 1888, Blatchley 1897, Lyon 1936). Cave deposits from Missouri (Parmalee and Jacobson 1959, Parmalee 1967), Illinois (Parmalee, et al. 1961, Parmalee 1967), Indiana (Bader and Hall 1960, Richards 1972, Parmalee, et al. 1978) and Ohio (Goslin 1955) indicate a historic distribution of *N. floridana* much further northward than the current distribution. In Indiana the species has been taken only from locations in Harrison County (Hickie and Harrison 1930) and Crawford County but the limits of its distribution in the state had not been determined. *Neotoma floridana* is currently included on the threatened list for Indiana (McReynolds, Whitaker and Gammon 1979) and the endangered list for Illinois (Nawrot and Klimstra 1976). Climatic factors have been proposed to explain the restricted range of the species in Indiana and Illinois (Richards 1972, Nawrot and Klimstra 1976).

The purpose of the present study was to determine the distribution of *N. floridana* in Indiana and to investigate limiting factors by comparing characteristics of active and inactive woodrat locations with those of areas lacking woodrats. Population estimates were conducted to evaluate the status of the species in the state.

Methods and Materials

To determine the distribution of *N. floridana* in Indiana, 100 potential sites were located on topographic maps (scale 1:24,000) of Perry, Crawford, Harrison, Floyd, Clark and Jefferson Counties and were inspected for evidence of woodrats. Sign included fresh cuttings, debris piles, fecal deposits and nests. Sites with questionable or old sign were livetrapped to verify their occurrence. Characteristics of all sites, including extent of cliff, number and quality of openings, rock type (limestone, sandstone or shale), and exposure, were recorded and comparisons made between active, inactive, and uninhabited sites to determine habitat requirements.

The availability of potential den sites was assessed at six *Neotoma* localities. Openings and crevices were judged to be potential den sites if they were similar in characteristics to active den sites. Active and potential den sites were counted and described for lengths of cliff from 480 to 1470 m ($\bar{X}$ = 767 m). The relationship between potential den site density and *Neotoma* density was tested by calculating Pearson's correlation coefficient for these two variables.

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Neotoma populations were estimated at six sites using a mark-recapture method. Forty-four livetraps set for three consecutive nights and one week later for two additional nights would generally trap all woodrats within a trapping site. Traps were baited with peanut butter and rolled oats and set at or near all *Neotoma* dens, fecal deposits and cutting piles within the area. Population estimates are given as number of animals per 1000 m of cliff for each site. A statewide estimate of the *Neotoma* population was attempted by determining the amount of available habitat in the state and applying the most appropriate population estimate. Ohio River bluffs within the range of *Neotoma* were measured on topographic maps and categorized as being most similar in site characteristics to one of the six sites where estimates had been made. Lengths of cliffs in each category were totalled and the density estimate applied to the total length. Population estimates for all categories were then totalled for the state estimate.

Results and Discussion

A total of 100 sites was inspected for evidence of woodrats (Figure 1). Overlapping of sites that were too close to be represented by more than one point accounts for the discrepancy between the number of sites checked and the number of points on the map. A more detailed view of *Neotoma* distribution in Perry, Crawford and Harrison Counties is given in Figure 2. Twenty-four sites had evidence of woodrats; twenty sites harbored active populations while four were inactive sites where only old sign was observed. Active sites were restricted primarily to the limestone bluffs along the Ohio River from the Little Blue River in Crawford Co. east to Evan's Landing, Harrison Co. (Figure 2).

Examination of active *Neotoma* sites with respect to cliff extent, exposure, number and types of openings and rock type resulted in a characterization of sites that are suitable for woodrats in Indiana. All active cliff sites (N = 19) have a southern component to their exposure ranging from SW to ESE. One active site is a cave not associated

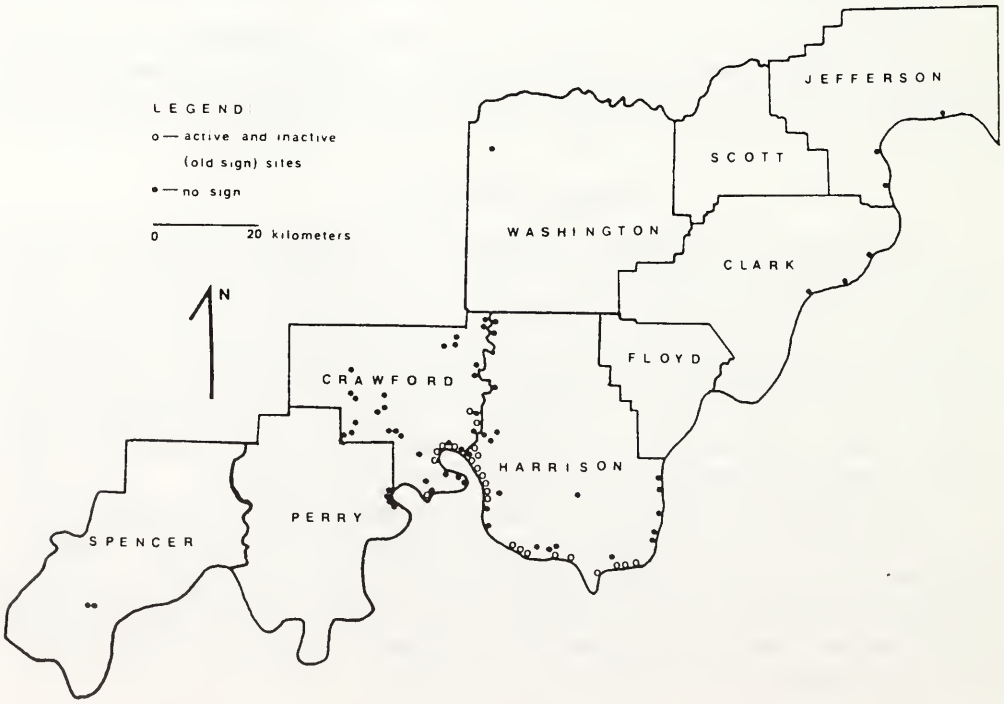

FIGURE 1. Locations of Sites Inspected for Evidence of *Neotoma floridana* in Southern Indiana.

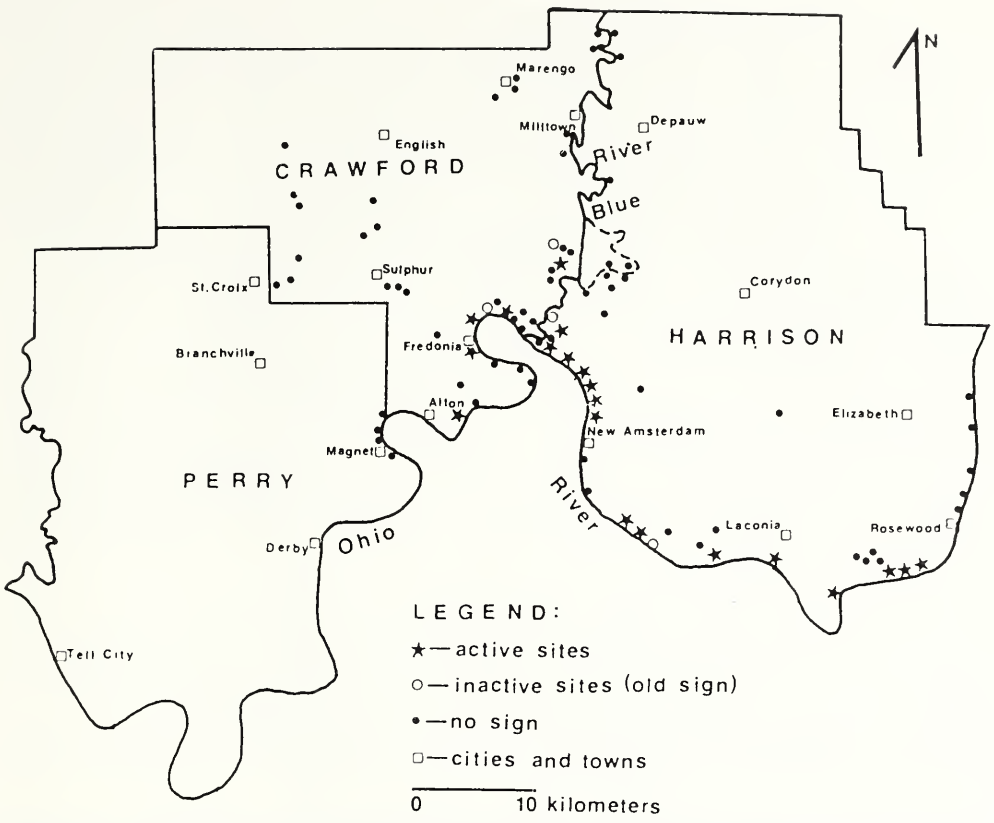

FIGURE 2. Distribution of *Neotoma floridana* in Indiana (dashed line corresponds to Blue River).

with cliffs. All but two sites (nN10 and nN17) are associated with extensive bluffs along the Ohio River. These two sites are dry caves without running water. Most caves not associated with cliffs along the Ohio River that were inspected tended to be wet caves and did not harbor woodrats. Moisture may be an important factor on cave sites not associated with cliffs. Caves or cave-like openings were present on 13 of 20 active sites (65.0%) and all active sites had moderate to abundant numbers of crevices or openings suitable for woodrat dens. The relationship between number of potential dens sites and woodrat densities was examined for seven *Neotoma* sites (Figure 3). The two variables are highly correlated ($r = 0.932$) indicating that the availability of den sites may be an important factor determining the density of woodrats. All active sites were located in limestone bedrock. Sandstone sites that satisfied exposure and cliff extent requirements generally lacked sufficient numbers of openings suitable as den sites. Appropriate characteristics for a site to harbor woodrats therefore, appear to be extensive limestone cliffs with a southern component to their exposure and suitable rock formations for den sites. Dry caves not associated with cliffs and abandoned buildings provide possible alternative habitats.

Seventy-six sites harboring no woodrats were examined to test the hypothesis that the above factors are in fact determining the distribution of woodrats. Seventy-four of 76 sites could be judged unsuitable as *Neotoma* habitat based on extent of cliff, abundance of openings, exposure and isolation. Two remaining sites that satisfied these requirements, but did not harbor woodrats may be lacking an additional factor that was not examined.

Woodrat populations were estimated by mark and recapture on six sites. A total of 1253 trap-nights resulted in 335 captures of 115 animals. Fifty-three males (46.1%)

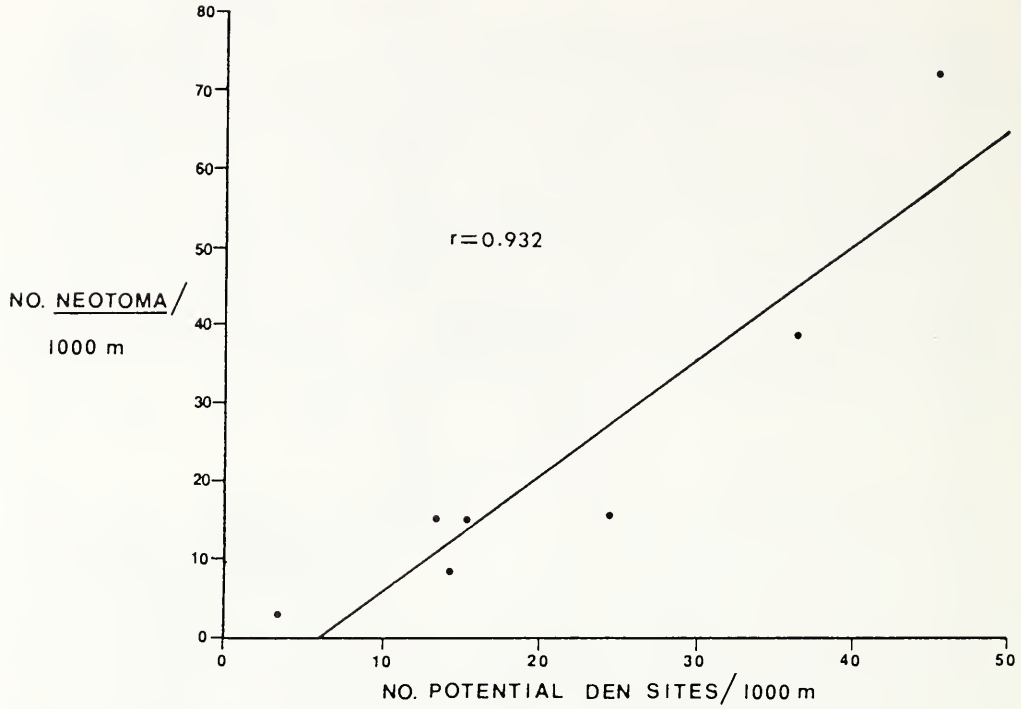

FIGURE 3. Relationship between *Neotoma* Density and Density of Potential Den Sites.

and 61 females (53.0%) were captured for a sex ratio of 0.87:1. The sex of one animal could not be determined. There were 143 captures of males (2.7 captures per male) and 191 captures of females (3.1 captures per female). This difference is due to the greater tendency for males to wander away from den sites and has been reported previously by Rainey (1956). Population estimates for individual sites are given in Table 1. Woodrat densities averaged 27.5 animals per 1000 m of cliff and ranged from 8.3 to 71.9 animals per 1000 m. Variation in densities between sites is probably most closely related to the availability of den sites (Figure 3). The density of juniper (*Juniperus virginiana*), however, was also positively correlated with woodrat densities ($r = 0.768$) and may be an important factor influencing population levels. Interestingly, woodrat densities were not strongly correlated ($r = -0.478$) with the density of Tree-of-heaven (*Ailanthus altissima*), the major food of Indiana woodrats. Site 82 harbored the greatest density of woodrats (71.9 per 1000 m) and also yielded the greatest number of cap-

TABLE 1. Estimated woodrat densities on six Ohio River bluff sites in extreme southern Indiana.

Site #	# Neotoma	Length of Cliff Censused (m)	# Neotoma/ 1000 m Cliff	# Captures/ 100 tn
1	15	930	16.1	30.6
2	12	780	15.4	17.4
8	4	480	8.3	5.5
30	22	1470	15.0	20.2
82	41	570	71.9	50.5
98	21	545	38.5	28.2
			$\bar{X} = 27.5$	

tures per unit effort. Over half of the trapping effort resulted in captures on this site (Table 1). The lowest densities were obtained on site 8 where only four woodrats were trapped for an estimated density of 8.3 per 1000 m of cliff. The site also produced the smallest return per unit trapping effort with only 5.5 captures per 100 trap-nights.

Measurements from topographic maps yielded an estimate of 43,855 m of Ohio River bluff present within the range of *N. floridana* in Indiana. All Ohio River bluffs occurring from the Little Blue River in Crawford Co. east to Evan's Landing in Harrison Co. were included except those areas that were surveyed and found to lack woodrats. This figure is considered to be an estimate of habitat available to woodrats in the state although some caves occurring away from the Ohio River probably harbor small populations. If the mean value of 27.5 *Neotoma* per 1000 m of cliff is applied to this figure a statewide estimate of 1206 animals results. This is probably an overestimate of the state population due to the uneven distribution of available cliff as being most similar in site characteristics to one of the sites where population estimates had been made and then to apply that estimate to the total length in each category. Lengths of cliff assigned to each site category were as follows:

Site #	Length of Cliff
1	3855 m
2	7373 m
8	9181 m
30	17422 m
82	1084 m
98	4940 m

A state estimate of 781 woodrats were obtained using this method. *Neotoma floridana* is currently included on the threatened list for Indiana (McReynolds, Whitaker and Gammon, 1979); however, based on this estimate and the restricted range of the species in the state (Figure 2) it is recommended that the species be elevated to "endangered" status.

Previously known localities for *N. floridana* in Indiana include Tobacco Landing (Hickie and Harrison 1930), Harrison State Forest (Kirkpatrick and Conaway 1948) and a site 3 mi. SE of Wyandotte Cave (Mumford and Whitaker 1982) in Harrison Co. and Wyandotte Cave (Mumford and Whitaker 1982) in Crawford Co. Mumford (1969) discounted a report of *Neotoma* occurring 5 mi. SW of Bloomington (Wayne 1960) as being *Rattus norvegicus*. Rose (1982) reported the occurrence of a single *Neotoma* skull among 630 prey items in Barn owl pellets and a woodrat colony in the Coal Knobs area of Spencer County. The skull has been lost, however, and I have since inspected the Coal Knobs site and found no evidence of woodrats. Whitaker (unpublished) also examined this area and additional Barn owl prey items from the same area and found no evidence of woodrats. Although the area has some sandstone outcrop, it is generally unsuitable for *Neotoma*.

It is clear from "Recent" fossil evidence that the Eastern woodrat once had a much more extensive distribution in Indiana than it presently does. Bader and Hall (1960) reported *N. floridana* remains "probably less than a few hundred years old" from Sullivan's Cave, 1.5 mi. W of Springville in Lawrence County. Richards (1972) reported woodrat bones from ten sites in Indiana as far north as western Monroe County and as far east as Jennings County. Based on fauna associated with these deposits he estimated their age to be a few thousand years old. Parmalee, Munson and Guilday (1978) found woodrat remains of late Pleistocene age at Harrodsburg Crevice in Monroe County. The present and historic distributions of *N. floridana* in Missouri, Illinois

and Ohio parallel the situation in Indiana with present distributions restricted to extreme southern regions and more widespread historic distributions.

As indicated from "Recent" fossil evidence, *N. floridana* probably occupied most of the karst region of southern Indiana prior to the Wisconsin glaciation. Parmalee, Munson and Guilday (1978) proposed that extreme periods of climatic fluctuation during the late Wisconsin exterminated northern populations and that woodrats have failed to repopulate since that time. The southern-most advance of the glacial boundary lies immediately north of Monroe County and brought boreal conditions there. Richards (1972) indicated, however, that temperature alone would not seem to play an important role in the distribution of the species since it ranges through the cooler Appalachian Mountains. He proposed that some other ecological factor, possibly an indirect result of a mild climatic change, caused the depopulation, There is some evidence, however, that woodrats may be sensitive to temperature changes. Brown and Lee (1969) demonstrated a "Bergmann's Response" (i.e. large body size in northern latitudes) in four species of woodrats (*Neotoma lepida, N. cinerea, N. albigula* and *N. fuscipes*). Only those homeotherms in which environmental temperature has profoundly influenced reproduction and mortality would be expected to show such a response. Nawrot and Klimstra (1976) and Fitch and Rainey (1956) attributed population declines to below-average temperatures and above-average snowfall in winter in Illinois and Kansas, respectively.

During depopulation of northern areas in the late Wisconsin, woodrats were probably able to survive due to the milder winters of extreme southern Indiana. Current populations occupy cliff sites with southern exposure and abundant openings suitable for den sites and it is likely that these sites were also occupied at this time. Southern exposure cliffs provide a microhabitat that is significantly warmer than surrounding microhabitats. Herbaceous plant species flowered as early as 19 February (*Cardamine parviflora*) on southern exposure cliffs in Harrison County, Indiana and many early spring species on these sites were flowered one to two weeks earlier than in adjacent woodlands. Crim (1961) reported that 95% of 370 sites of woodrat activity were situated near SW facing rock formations in southern Illinois. Strong positive correlation between den site availability and population density (Figure 3) indicates that the presence of suitable rock formations for den sites is an important limiting factor. In Illinois, woodrats were eliminated from marginal habitat with only a few crevices in severe winter weather but not from sites with many crevices, faults and ledges (Nawrot and Klimstra 1976). Deep crevices and especially caves may serve to moderate temperature extremes during periods of severe weather. Several authors (Heisler 1941, Sands 1951, Crum 1961) have reported the availability of suitable rock shelters as the most important limiting resource for *N. floridana* at the northern limits of its range.

Woodrats have been unable to repopulate the karst area in Indiana probably due to their slow migration (Richards 1972) and reproduction rates (Worth 1950). Nawrot and Klimstra (1976) indicated that dispersion from present populations in Illinois may be hindered by the obstruction of natural dispersal routes by man. These barriers include reservoir inundation of extensive outcrops, isolation of outcrops by agricultural lands, residential development, stone quarries and highways. These authors felt that these barriers would be sufficient to prevent natural repopulation of the former range of the woodrat in Illinois. Similar conditions may be contributing to the hindrance of migration in Indiana.

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