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REASSESSMENT OF THE ALLEGHENY WOODRAT (*NEOTOMA MAGISTER*) IN INDIANA

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ABSTRACT. In the early 1980s, extant populations of the endangered Allegheny woodrat (*Neotoma magister*) in Indiana were reported from 20 sites (18 bluffs, 2 caves) adjacent to the Ohio River in Harrison and Crawford Counties. To assess the species' current status, live trapping surveys were conducted at 17 sites (access to the remaining three was denied) in 1991–1992. A total of 101 woodrats (50♂:51♀) was captured 144 times in 1551 trap-nights at 12 (11 bluffs, 1 cave) of the 17 sites. No woodrats were captured in Wyandotte Cave or on four bluffs in Crawford (n = 3) and Harrison (n = 1) Counties. Population declines were evident at four additional bluff sites. Existing populations were mostly limited to south-facing limestone cliffs bordering the Ohio River from Evans Landing in Harrison County downstream to Alton in Crawford County, the same range limits reported a decade earlier. To search for new populations, 41 sites in Clark, Crawford, Floyd, Harrison, Jefferson, Monroe, Orange and Perry Counties were inspected for woodrat activity in 1992–1993. Woodrats were found at only three sites (2 caves, 1 bluff) in Harrison County, which extended the species' known range in Indiana 2 km east along the Ohio River. Biennial monitoring of extant populations yielded 128 woodrats (54♂:74♀) at 14 sites in 1993–1994 and 123 woodrats (50♂:73♀) at 12 of 15 sites in 1996. Marked individuals comprised 9.4% and 10.6% of the total catch in 1993–1994 and 1996, respectively. Allegheny woodrats were most abundant on Bull's Point Bluff, Harrison-Crawford State Forest, and Rabbit Hash Ridge, which comprised >90% of the individuals taken in each biennial survey. Future conservation efforts should include periodic monitoring of extant sites and inspection of formerly-occupied sites, identification of factors limiting woodrat populations, and development of management recommendations for land owners and managers.

Keywords: Allegheny woodrat, conservation, distribution, Indiana, *Neotoma magister*, population, survey

The Allegheny woodrat (*Neotoma magister* Baird) inhabits cliffs, outcrops, talus slopes, caves, abandoned mines and other rocky habitats in deciduous forests of the eastern United States. *Neotoma magister* (= *N. pennsylvanica* Stone) was originally recognized as a distinct species (Goldman 1910) but was later reclassified as a subspecies of the eastern woodrat (*N. floridana* Ord; Burt & Barkalow 1942; Schwartz & Odum 1957). However, genetic and morphological studies (Hayes & Harrison 1992; Hayes & Richmond 1993) concluded *N. magister* warrants classification as a separate species. Historically, Allegheny woodrats occupied the Appalachian Mountain system from eastern New York southward to northern Alabama and west into Kentucky, Indiana and Tennessee (Poole 1940). Native populations have declined recently, particularly in the northeastern United States and the species has been extirpated from New York. Additionally, woodrats have restricted or reduced distributions in New Jersey, Pennsylvania, Maryland, Indiana and Ohio (Whitaker & Hamilton 1998). Causes for the declines are unclear; but potential factors include habitat fragmentation, increased predation, changes in forest composition, severe winter weather, infection from the parasitic raccoon roundworm (*Baylisascaris procyonis*), and decreased mast production due to gypsy moth (*Lymantria dispar*) invasion (see Balcom & Yahner 1996).

Allegheny woodrats have been listed as endangered in Indiana since 1984 and are limited to the unglaciated, south-central portion of the state. The species was first documented in 1930 from Harrison County (Hickie & Harrison 1930) although earlier accounts (e.g., Cope 1872) refer to what were probably woodrats in Wyandotte Cave in Crawford County. Cave deposits indicate woodrats once ranged as far north as Owen County (Richards 1972; 1986), but the species' modern range is restricted to the limestone escarpments that

border the Ohio River in extreme southern Indiana. Mumford (1975) found no evidence of woodrats in the Hoosier National Forest but reported three active colonies in Harrison and Crawford Counties. Similarly, Whitaker (1979) found no sign of woodrats at 109 sites in the Hoosier National Forest. Mumford & Whitaker (1982) list specimen records from Crawford and Harrison Counties and other records from five additional counties (Jennings, Lawrence, Monroe, Orange and Owen). Cudmore (1985) examined 100 sites in Clark, Crawford, Harrison, Jefferson, Perry, Spencer and Washington Counties but found evidence of extant populations at only 20 sites (18 bluffs, 2 caves) in Crawford and Harrison Counties. Four additional sites in Crawford and Harrison Counties had only old sign and were considered inactive.

Given population declines elsewhere, field surveys were conducted from 1991 through 1996 to reassess the status and distribution of the Allegheny woodrat in Indiana. The objectives were to determine the occurrence and relative abundance of woodrats at the 24 sites reported by Cudmore (1985), to assess population trends at occupied sites, and to search for new localities because rocky bluffs that appear suitable for woodrats are abundant along the Ohio River.

METHODS

Site selection and field searches.—The 24 sites reported by Cudmore (1985) were transcribed from topographic maps (1:24,000) at Indiana State University. Each site was visited to locate suitable rock features (e.g., overhangs, deep crevices and ledges) and to search for evidence of woodrats. Allegheny woodrats leave conspicuous sign such as fresh plant cuttings, hard mast caches, debris piles, nests and fecal deposits; consequently, their presence can often be determined by visual inspection. The rim, base, accessible tiers and any abandoned buildings were inspected at bluff sites. At caves, the entrance, twilight zone, adjacent outcrops and passages reported by previous researchers to have woodrat activity were examined.

Searches for new localities were conducted in 1992 and 1993. Potential sites were identified from topographic maps based on vertical relief and from reports of woodrat activity received from cavers. These sites were then inspected specifically for woodrat sign or while conducting other activities (i.e., bat hibernacula censuses). They were subsequently trapped only if fresh sign was found during initial searches.

Live trapping.—Single-door live traps (40.6 cm long, 12.7 cm wide, 12.7 cm high) baited with sliced apples were used to capture woodrats. To reduce disturbance during the peak reproductive period (i.e., April and May; Cudmore 1983), trapping was conducted from June through October. The 20 sites reported occupied by Cudmore (1985) were surveyed in October 1991 and from June through October 1992. At each bluff site, 25–59 traps ($\bar{x}$ = 42.1) were set for two consecutive nights ($\bar{x}$ trap-nights per site = 84.2; SD = 23.0). The single exception was Cold Friday Hollow Bluff (site #75), which was surveyed in two sessions due to its length (>1500 m), abundance of optimal habitat, and fresh woodrat sign. Trap effort at the two caves ($\bar{x}$ = 60.0 trap-nights; SD = 14.1) depended on passage length and complexity, presence of woodrat sign and availability of rock outcrops near the entrance. At all sites, traps were placed near activity areas (e.g., latrines, food caches, nests) and throughout suitable habitat found during initial searches. Traps were set in late afternoon, checked early the following morning, and checked and removed on the second morning. Sex, age class, body weight (to nearest 2.5 g) and reproductive status were noted for each woodrat. A numbered Monel size #1 tag was placed in each ear. Unless reproductive status indicated otherwise, pelage coloration and body weights (Mengak 1991) were used to assign age class (i.e., juveniles: <175 g; subadult: 175–224 g; adult: ≥225 g).

Biennial monitoring program.—Once extant colonies were identified, either at new or previously-known sites, population trends were assessed by a biennial monitoring program. Occupied sites were live trapped in 1993–1994 and 1996 using standard survey protocol (i.e., *ca.* 40 traps for two consecutive nights). Traps were again placed near activity areas or at previous capture sites to assess site fidelity and survival. Captured woodrats were processed as previously described and released immediately after handling.

RESULTS

Surveys of sites occupied in 1980–1983.—Landowners granted permission to trap 17 (15

bluffs, 2 caves) of the 20 sites occupied by woodrats in the early 1980s. Average length of bluff surveyed was 928 ± 473 m. From October 1991 through October 1992, 101 woodrats (50♂:51♀) were captured 144 times in 1551 trap-nights at 12 (11 bluffs, 1 cave; Table 1) of 17 sites. Mean capture rate at occupied sites was 8.5 individuals/100 trap-nights (range: 1.2–26.8). Distribution by sex and age class was 32 adult ♂, 32 adult ♀, 6 subadult ♂, 12 subadult ♀, 11 juvenile ♂, and 7 juvenile ♀. Age of one male was not determined. An average of 8.4 woodrats was captured at occupied sites (range: 1–26), but only 6 sites yielded ≥5 animals. Evidence of reproduction at 10 sites included juvenile woodrats (6 sites), late-season subadults (2 sites), pregnant females (1 site) and a scrotal male (1 site). Latest capture dates for juveniles, lactating females and scrotal males were 24 September, 22 July and 25 October, respectively. Relative abundance at 10 occupied bluffs ranged from 2.5–25.0 woodrats/km of bluff ($\bar{x}$ = 11.1, SD = 7.8). These are minimal values because it is unlikely all resident woodrats were captured and populations may be greater at sites surveyed later in the season due to annual recruitment.

Eleven of 12 occupied sites were associated with extensive limestone bluff systems bordering the Ohio River (Fig. 1) from Evans Landing in Harrison County downstream to Alton in Crawford County (*ca.* 74 river km), the same range limits reported by Cudmore (1985). The other site, Potato Run Cave, was in Harrison-Crawford State Forest (HCSF) about 1.2 km from occupied bluff habitat. Only one confirmed site (Bull's Point Bluff) was in Crawford County; the remaining 11 were in Harrison County.

No woodrats were captured at five sites including Scenic View Bluff in Harrison County and Leavenworth Bluff, Lowe/Booth Bluff, South Fredonia Bluff and Wyandotte Cave in Crawford County (Table 1; Fig. 1). Suitable rock overhangs, crevices and ledges were common at several of these bluff sites; but no fresh sign or other recent evidence of woodrats was found. Access was denied to the three remaining sites (2 bluffs, 1 abandoned building) occupied by woodrats in the early 1980s. A cursory search of Mulzer #8 and Mulzer #97 bluffs near Mauckport revealed suitable rock features and old sign but no evidence of an extant population. The abandoned building (site #83) on privately-owned Nye Bluff lies between two occupied bluff sites on HCSF but was not visited.

The four sites (3 bluffs, 1 abandoned building) considered inactive by Cudmore (1985) were also searched to assess if woodrats had recolonized the sites (Table 1). However, no sign was found at Wildcat Cave and Mauckport Cemetery bluffs while Indian Hollow Bluff yielded only old sign (i.e., disheveled nest and food cache). The abandoned building on the Blue River at site #48 had been destroyed, and the surrounding habitat was unsuitable for woodrats. These four sites were not trapped during the study.

Searches for new localities.—From May 1992 through September 1993, 41 sites in Clark, Crawford, Floyd, Harrison, Jefferson, Monroe, Orange and Perry Counties were searched for evidence of woodrats. Most sites (n = 26; 68%) were associated with limestone outcrops or bluff systems along the Ohio River (Fig. 2) and averaged 879 ± 291 m in length. Nine caves were inspected, primarily during bat hibernacula censuses in January 1993. Two sites in the Hoosier National Forest, Derby Cemetery and Buzzard's Roost bluffs, had been examined previously by Whitaker (1979) while eight other bluff sites had been visited by Cudmore (1985).

Allegheny woodrats were confirmed at only three of 41 sites, all in Harrison County (Table 2). Two were small caves in HCSF ≤2.5 km of occupied bluffs on the Ohio River. Only one woodrat was captured in each cave during limited trapping sessions (i.e., 8–10 trap-nights per cave) in October 1992. The third locality, Noes Park Bluff (site #134), extended the known range of Allegheny woodrats about 2 km east from Rabbit Hash Ridge (Fig. 2). Seven woodrats, including 5 adults, 1 subadult, and 1 juvenile were captured at Noes Park Bluff in August 1993.

Evidence of former occupancy (e.g., old latrines, food caches, nests) was found at eight sites in Harrison (n = 4), Crawford (n = 3) and Monroe (n = 1) Counties (Table 2). Most (63%) were caves, which probably provided better conditions for preserving woodrat sign than those on exposed bluff sites. Although many bluffs had suitable overhangs, crevices and ledges, old sign was found only at Angelwing Arch (Crawford County) and Moore

Table 1.—Results of live trapping surveys for Allegheny woodrats at active (n = 20) and inactive (n = 4) sites reported by Cudmore (1985) in Crawford and Harrison Counties, Indiana, September 1991–October 1992. Previous status reported by Cudmore (1985): A = active; I = inactive. Ownership: HCSF = Harrison-Crawford State Forest; p = private. Relative abundance expressed as number of woodrats/km of bluff; estimates not provided for caves or bluff sites at which no woodrats were captured.

Site no.	Site name	Previous status	Ownership	Survey dates	Trap-nights	No. woodrats	Adults	Subadults & juveniles	Relative abundance
Crawford County									
10	Wyandotte Cave	A	HCSF	16–18 Oct 1991	70	0	0	0	—
14	Leavenworth Bluff	A	p	25–27 Aug 1992	116	0	0	0	—
15	Indian Hollow Bluff	I	HCSF	28 Sep 1992		old sign found; site not trapped			
30	Lowe/Booth Bluff	A	p	14–16 Sep 1992	98	0	0	0	—
36	South Fredonia Bluff	A	p	21–23 Oct 1992	46	0	0	0	—
39	Bull's Point Bluff	A	p	13–15 Oct 1992	102	7	3	4	3.7
40	Wildcat Cave Bluff	I	HCSF	12 Sep 1991		no sign found; site not trapped			
Harrison County									
1	Tobacco Landing	A	p	28–30 Jul 1992	116	2	0	2	2.5
2	Shelterhouse #2 Bluff	A	HCSF	2–4 Oct 1991	82	22	15	6	25.0
4	Scenic View Bluff	A	p	12–14 Aug 1992	70	0	0	0	—
7	Mauckport Cemetery Bluff	I	p	5 Aug 1992		no sign found; site not trapped			
8	Mulzer #8 Bluff	A	p	17 Aug 1992		old sign found; site not trapped (access denied)			
17	Potato Run Cave	A	HCSF	16–18 Oct 1991	50	1	1	0	—
19	Rabbit Hash Ridge - U	A	p	22–24 Jun 1992	55	8	4	4	10.4
20	Rabbit Hash Ridge - C	A	p	22–24 Jun 1992	62	2	2	0	4.8
21	Rabbit Hash Ridge - D	A	p	30 Jun–2 Jul 1992	76	10	7	3	18.3
47	The Narrows Bluff	A	p	20–22 Jul 1992	74	4	3	1	5.5
48	Blue River Building	I	HSCF	11 Sep 1991		building destroyed; surrounding habitat unsuitable			
75	Cold Friday Hollow Bluff	A	HCSF	9–11, 22–24 Sep 1992	252	26	17	9	16.7
81	Overflow Pond Bluff	A	p	1–3 Jun 1992	82	1	1	0	—
82	South HCSF Bluff	A	HCSF	8–10 Jun 1992	118	14	7	7	17.7
83	Nye Building	A	p			site not visited (access denied)			
97	Mulzer #97 Bluff	A	p	17 Aug 1992		old sign found; site not trapped (access denied)			
98	South Nye Bluff	A	HCSF	23–25 Oct 1991	82	4	4	0	6.0
	Total all sites				1551	101	64	36	11.1

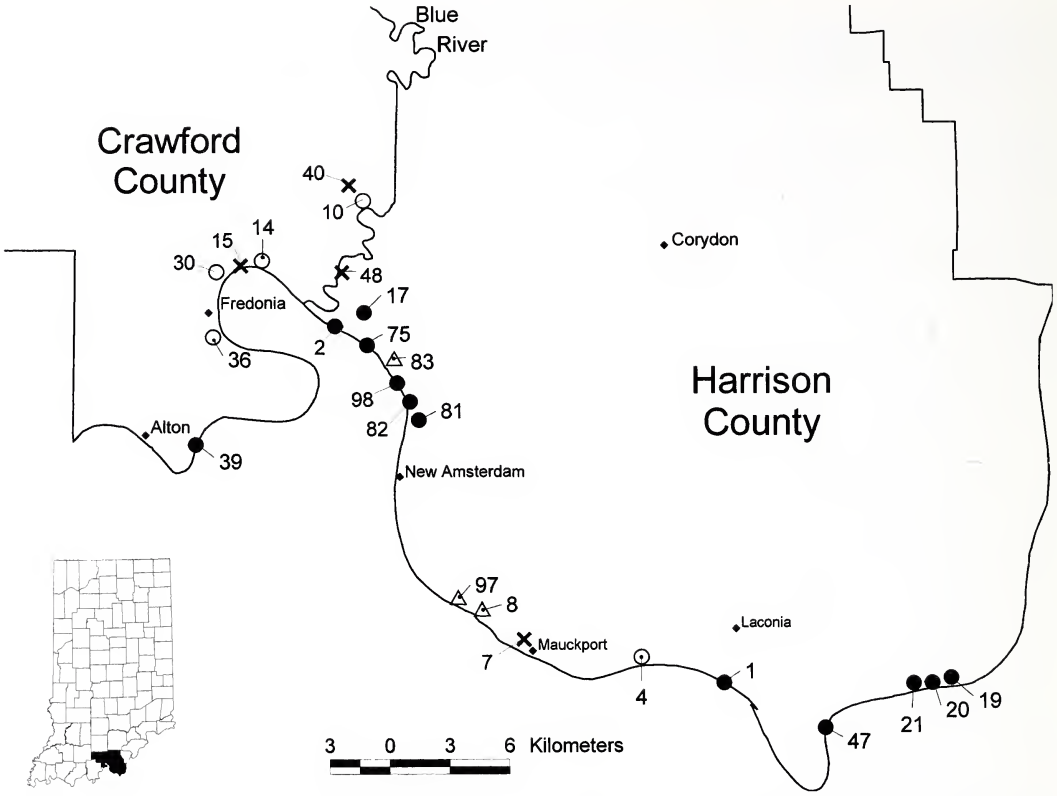

Figure 1.—Results of live trapping surveys at 20 active sites for Allegheny woodrats reported by Cudmore (1985) in Crawford and Harrison Counties, Indiana, September 1991–October 1992. Solid circles (●) denote sites occupied by woodrats (n = 12); open circles (○) denote sites at which no woodrats were captured (n = 5); open triangles (△) denote sites to which access was denied (n = 3). Crosses (×) denote inactive sites (n = 4) reported by Cudmore (1985).

Chapel Bluff and North New Amsterdam Bluff in Harrison County.

Biennial monitoring of extant sites.—In September–October 1993 and June–October 1994, 128 woodrats (54♂:74♀) were captured 216 times in 1136 trap-nights at 14 sites (11 bluffs, 3 caves) that were occupied in 1991–1992. This represents a 24% increase over the number of animals taken in 1991–1992, largely due to gains at bluff sites #39, #82 and #98 (Fig. 3). There was relatively little change noted at the remaining 11 sites. Twelve (6♀:6♂) of 128 woodrats (9.4%) were recaptures first taken in 1991–1992 as juveniles (n = 2), subadults (n = 5) or adults (n = 4). The identity of one adult male was unknown because both ear tags had been lost. Elapsed time between recapture dates ranged from 16–26 months ($\bar{x}$ = 22.8). Ten woodrats were recaptured at their original sites including six individuals (2♂:4♀) taken ≤10 m from their initial trap location. Three other woodrats (2♂:1♀), all juveniles or subadults in 1992, were recaptured two years later 45–255 m ($\bar{x}$ = 140) from their first capture site. A subadult male caught in June 1992 on site #82 was recaptured in October 1993 at site #98, about 1.2 km from his initial capture site.

From July–October 1996, 123 woodrats (50♂:73♀) were captured 206 times in 1207 trap-nights at 12 (11 bluffs, 1 cave) of 15 sites. This represents a 9% decline in the number taken in 1993–1994. No woodrats were captured at Overflow Pond Bluff, P.P. Pot Cave and Limekiln Hollow Cave. Few animals (≤3) were captured here previously, and only a single adult was caught in either cave in 1992 and 1994. Also, marked declines were evident at bluff sites #82 (−48%) and #98 (−55%) in HCSF (Fig. 3). Compared to

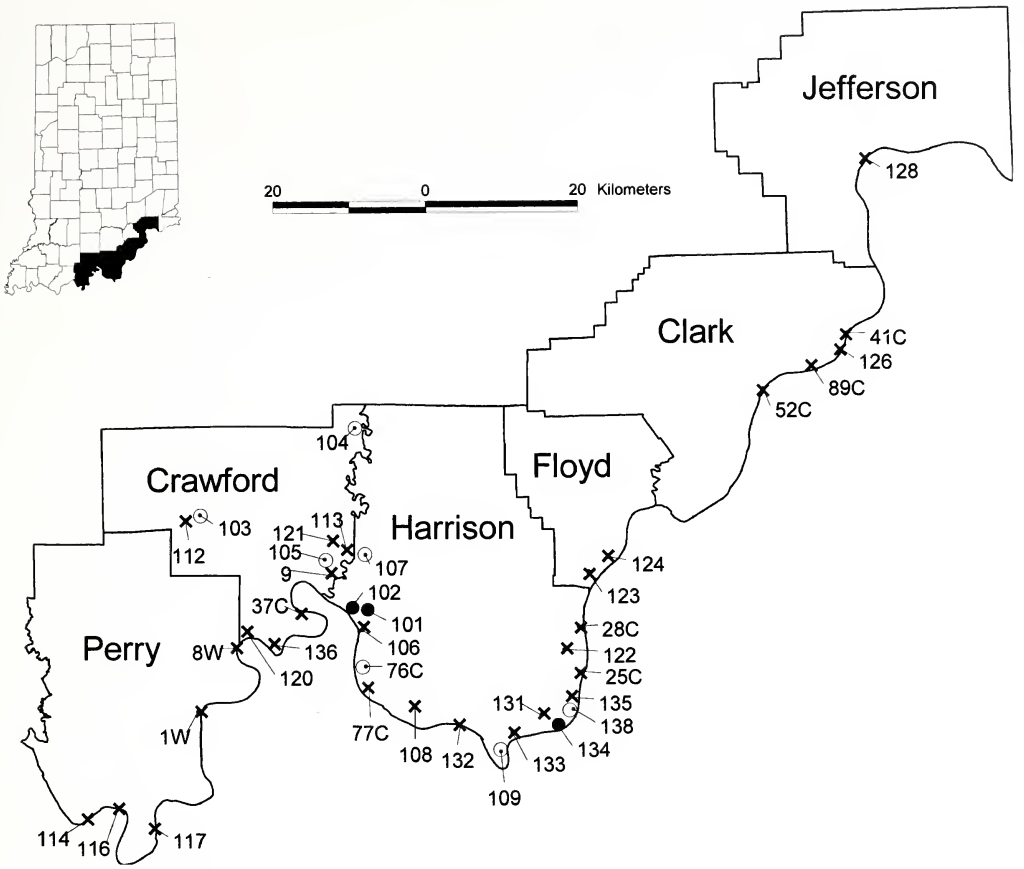

Figure 2.—Distribution of sites (n = 39) inspected for Allegheny woodrats in Clark, Crawford, Floyd, Harrison, Jefferson and Perry Counties, Indiana, May 1992–September 1993. Solid circles (●) denote sites at which woodrats were found (n = 3); open circles (○) denote sites at which old sign was found (n = 7); crosses (×) denote sites at which no sign was found (n = 29). Sites #110 (Saltpeter Cave, Monroe County) and #111 (Elrod Gulf, Orange County) not shown.

1993–1994, eight sites yielded 1–10 ($\bar{x}$ = 3.5) fewer woodrats; but five other sites yielded 1–7 ($\bar{x}$ = 3.2) more woodrats. Thirty-two woodrats were captured at Bull's Point Bluff (site #39), nearly a five-fold increase since 1992 and the greatest number taken during this study. Thirteen (3♂:10♀) of 123 woodrats (10.6%) were recaptures first taken in 1993–1994 as juveniles (n = 1), subadults (n = 2) or adults (n = 8). The identity of two males was unknown because they had lost their ear tags. The remaining 11 were recaptured at their original sites including eight individuals (1♂:7♀) taken ≤5 m from their initial capture site. Elapsed time between recapture dates for these 11 woodrats ranged from 22–37 months ($\bar{x}$ = 25.0).

DISCUSSION

Allegheny woodrats were found at 12 of 17 (71%) sites occupied over a decade ago and have essentially the same distribution as reported by Cudmore (1985). However, their occurrence within this range is disjunct, likely due to the availability of complex cliffs that provide suitable fissures and crevices for cover and nest sites. Fresh sign (e.g., latrines, green cuttings) was evident at occupied sites, and its presence was a reliable indicator of an extant population. Failure to capture woodrats at five recently-occupied sites, however, may not provide conclusive evidence of a local extinction. Portions of bluff sites were inaccessible for field searches or live trapping. Fur-

Table 2.—Results of field searches for new localities for Allegheny woodrats at 41 sites in Clark, Crawford, Floyd, Harrison, Jefferson, Monroe, Orange, and Perry Counties, Indiana, May 1992–September 1993. Sites with C (n = 8) denote those visited by Cudmore (1985); sites with W (n = 2) denote those visited by Whitaker (1979). Ownership: DNP = Division of Nature Preserves; HCSF = Harrison-Crawford State Forest; HNF = Hoosier National Forest; TNC = The Nature Conservancy; p = private.

Site no.	Site name	County	Ownership	Search period	Results
41C	Blue Ridge Bluff	Clark	p	Jul 1993	no sign
52C	Devil's Backbone	Clark	p	Jul 1993	no sign
89C	Bull Creek Bluff	Clark	p	Jul 1993	no sign
126	Bull Creek Cemetery Bluff	Clark	p	Jul 1993	no sign
9	Wyandotte Lake Bluff	Crawford	HCSF	Jan 1993	no sign
31	Saltpeter Cave	Crawford	HCSF	Jan 1993	no sign
37C	Artist's Point Bluff	Crawford	p	Sep 1993	no sign
103	Angelwing Arch	Crawford	HNF	Oct 1992	old sign
104	Robinson's Ladder Cave	Crawford	p	Jan 1993	old sign
105	Turtle Cave	Crawford	HCSF	Jan 1993	old sign
112	Hemlock Cliffs	Crawford	HNF	Oct 1992	no sign
120	Section 31 Bluff	Crawford	HNF	Jul 1993	no sign
121	Little Wildcat Cave	Crawford	HCSF	Jun 1993	no sign
136	Little Blue River Bluff	Crawford	p	Aug 1993	no sign
123	Brock-Sampson Glade	Floyd	DNP	Jun 1993	no sign
124	Gap Hollow Bluff	Floyd	p	Jun 1993	no sign
25C	Fishtown Bluff	Harrison	p	Jun 1993	no sign
28C	Blunk Point Bluff	Harrison	p	Jun 1993	no sign
76C	North New Amsterdam Bluff	Harrison	p	Jul 1993	old sign; no woodrats captured in Aug 1996
77C	South New Amsterdam Bluff	Harrison	p	Jul 1993	no sign
101	P. P. Pot Cave	Harrison	HCSF	May 1992	fresh sign; 1 woodrat captured in Oct 1992
102	Limekiln Hollow Caves	Harrison	HCSF	May 1992	fresh sign; 1 woodrat captured in Oct 1992
106	Cold Friday Hollow Karst	Harrison	HCSF	Oct 1992	no sign
107	Formation Pit Cave	Harrison	HCSF	May 1992	old sign
108	Scenic View Overlook Bluff	Harrison	county	not specified	no sign
109	Wallier Cave	Harrison	p	Aug 1992	old sign
122	Stoner Hill Bluff	Harrison	TNC	Aug 1993	no sign
131	Teeple Glade	Harrison	TNC	Jun 1993	no sign

Table 2.—Continued.

Site no.	Site name	County	Ownership	Search period	Results
132	Mile 643 Bluff	Harrison	p	Jul 1993	no sign
133	Mosquito Creek Bluff	Harrison	p	Aug 1993	no sign
134	Noes Park Bluff	Harrison	p	Jul 1993	fresh sign; 7 woodrats captured in Aug 1993
135	Rosewood Bluff	Harrison	p	Jul 1993	no sign
138	Moore Chapel Bluff	Harrison	p	Sep 1993	old sign
128	Devil's Backbone - Madison	Jefferson	p	Sep 1993	no sign
110	Saltpeter Cave	Monroe	p	Jan 1993	old sign
111	Elrod Gulf	Orange	p	not specified	no sign
1W	Derby Cemetery Bluff	Perry	p	Jul 1993	no sign
8W	Buzzard Roost Bluff	Perry	HNF	Jul 1993	no sign
114	Cannelton Bluff	Perry	HNF	Jun 1993	no sign
116	Dodd Bluff	Perry	p	Jul 1993	no sign
117	Adams/Sample Bluff	Perry	p	Jul 1993	no sign

ther, traps were set for only two consecutive nights and some resident woodrats may have avoided capture. To illustrate, 31 of 75 (41%) individuals taken on the second trap night in 1991–1992 were new captures. Nonetheless, Allegheny woodrats appear to have been extirpated from at least two sites. The abandoned building at site #36 was destroyed, and no sign or woodrats were found in the cliffs below the foundation. No evidence of woodrats was found in Wyandotte Cave (site #10), which is >6 km disjunct from established populations on the Ohio River. Hickie & Harrison (1930) and Lyon (1936) were unable to find woodrat sign in Wyandotte Cave, but *Neotoma* tracks were observed >500 m from the entrance in 1973 (Mumford & Whitaker 1982). We found no sign in areas of the cave reported to have woodrat activity, and personnel at Wyandotte Cave were unaware of any food caches, latrines or nests. Several of our traps were sprung or had chewed bait, which suggests *Peromyscus* spp. were present.

Cudmore (1985) reported an overall abundance of 27.5 woodrats/km of cliff, over twice that found in 1991–1992 (11.1 woodrats/km). Despite differences in survey protocol, population declines were apparent at 4 of 5 sites (Table 3). Lowe/Booth Bluff, where Cudmore (1985) captured 22 animals and found 12 active dens, yielded no woodrats and only old sign. Marked declines were also evident at Tobacco Landing, South HCSF Bluff and South Nye Bluff. In contrast, the population at Shelterhouse #2 increased from its previous level.

The original site boundaries established by Cudmore (1985) were maintained for consistency; but recapture data suggest regular movement between adjacent sites, particularly in HCSF and at Rabbit Hash Ridge. A subadult male from South HCSF Bluff was recaptured 16 months later on adjacent South Nye Bluff, about 1.2 km from his initial capture site. A subadult female caught on South HCSF Bluff in August 1994 was recaptured one month later on Cold Friday Hollow Bluff, nearly 3 km from her initial trap site. On Rabbit Hash Ridge, five woodrats (4 adult ♂, 1 subadult ♀) were recaptured within three weeks on adjacent sites 80–960 m ($\bar{x}$ = 450 m) from their initial trap site including an adult male that had moved 960 m overnight.

In Indiana, Allegheny woodrats were most abundant on Harrison-Crawford State Forest,

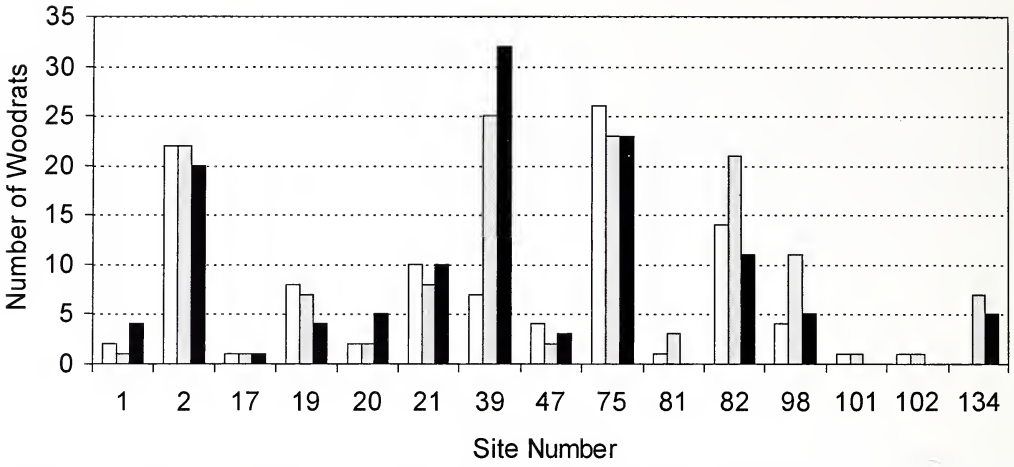

Figure 3.—Number of Allegheny woodrats captured during 1991–1992 (open bar), 1993–1994 (shaded bar) and 1996 (solid bar) surveys at 15 sites in Crawford and Harrison Counties, Indiana. Site #134 was not trapped in 1991–1992. No woodrats were captured in 1996 at sites #81, #101 and #102.

Rabbit Hash Ridge and Bull's Point Bluff. These three complexes support relatively large populations that accounted for >90% of the woodrats captured in 1991–1992, 1993–1994 and 1996. Population declines at individual sites within these complexes may be ameliorated by immigration of woodrats from adjacent, occupied habitats. For example, movement among the three contiguous sites on Rabbit Hash Ridge was common; and when treated as a unit, the total population remained relatively small yet stable (i.e., 20 woodrats in 1992, 17 in 1994 and 19 in 1996). Additional opportunities for interchange may be available from Noes Park Bluff (site #134), which is <2 km from Rabbit Hash Ridge. In contrast, the long-term viability of other sites (e.g., The Narrows, Tobacco Landing) is suspect because habitats were marginal or sites were spatially isolated from larger populations. Without immigration of dispersing woodrats from nearby sites, small localized populations may be more vulnerable to extirpation. Similarly, the three sites at which no woodrats were captured in 1996 (i.e., Overflow Pond Bluff, P.P. Pot Cave, Limekiln Hollow Cave) had few crevices and fissures or were disjunct from established bluff populations. Overflow Pond Bluff is probably periodically used by woodrats from adjacent cliffs in HCSF. However, P.P. Pot and Limekiln Hollow caves can support few animals because they are small, and adult woodrats are generally intolerant of one another (Wiley 1980).

Richards (1986) found fossil evidence of Allegheny woodrats throughout Indiana's karst region as far north as Owen and Shelby Counties, *ca.* 145 km north of present range and suggested indirect effects of climatic change (e.g., extended snow cover, availability of winter foods) caused the ancient depopulation. Marginal habitats such as small, wet caves and discontinuous rock outcrops with few crevices dominated most of this historic range. While prolonged factors such as climatic change may have caused a dramatic, long-term range reduction, woodrats have been extirpated or, at least, greatly reduced in <15 years from optimal habitats (i.e., south-facing limestone bluffs) within their current distribution. Balcom & Yahner (1996) found more residential, cropland and other agricultural cover at historic than occupied sites in Pennsylvania and claimed these land uses favored higher populations of ubiquitous predators such as great horned owls (*Bubo virginianus*) and raccoons (*Procyon lotor*). Both species have been implicated in woodrat declines in the northeast United States from increased predation or exposure to *Baylisascaris procyonis* (Balcom 1994; Balcom & Yahner 1996; McGowan 1993). In 1996, an adult female woodrat from Shelterhouse #2 in HCSF was found infected with raccoon roundworm

Table 3.—Number of Allegheny woodrats captured, capture rate, and relative abundance in 1980–1983 (Cudmore 1985) and 1991–1992 (this study) at 6 bluff sites in Crawford and Harrison Counties, Indiana. Capture rate expressed as number of individuals/100 trap-nights. Relative abundance expressed as number of woodrats/km of bluff. [1] Forty-four traps set for 3 consecutive nights and for 2 additional nights one week later. [2] At 5 sites listed above, 40–59 traps ($\bar{x}$ = 49.7) set for 2 consecutive nights.

Site no.	Site name	1980–1983 Survey[1]			1991–1992 Survey[2]		
		No. woodrats	Capture rate	Relative abundance	No. woodrats	Capture rate	Relative abundance
1	Tobacco Landing	15	30.6	16.1	2	1.7	2.5
2	Shelterhouse #2 Bluff	12	17.4	15.4	22	26.8	25.0
8	Mulzer #8 Bluff	4	5.5	8.3	site not trapped (access denied)		
30	Lowe/Booth Bluff	22	20.2	15.0	0	0.0	—
82	South HCSF Bluff	41	50.5	71.9	14	11.9	17.7
98	South Nye Bluff	21	28.2	38.5	4	4.9	6.0

larvae. It exhibited clinical neurologic disease; and eight *B. procyonis* larvae were recovered including one from the brain, four from the anterior carcass and three from the posterior carcass (K.R. Kazacos pers. comm.). *Baylisascaris procyonis* is transmitted from eggs shed in raccoon feces and is fatal to a wide range of secondary hosts (Kazacos & Boyce 1989). Woodrats may be particularly susceptible to infection because of their caching behavior, which includes raccoon feces (pers. obs.); but the prevalence of *B. procyonis* in woodrat habitat and its potential role in population declines in Indiana are unknown.

Future conservation efforts for Allegheny woodrats in Indiana should focus on identification of factors limiting extant populations (e.g., habitat fragmentation, raccoon roundworm infection, increased predation, changes in forest composition, availability of hard mast) and development of effective management strategies. With few exceptions, the biennial monitoring program initiated in this study detected relatively little change in woodrat populations at individual sites over a six-year period. Consequently, a less frequent monitoring schedule (e.g., 4–5 years) could be adopted at extant sites to determine species' presence and to monitor natural population fluctuations. Previously-occupied sites should be inspected periodically for fresh sign to determine if woodrats have recolonized former habitats.

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