2004. Proceedings of the Indiana Academy of Science 113(1):66–75

BATS OF THE NAVAL SURFACE WARFARE CENTER AT CRANE, INDIANA

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ABSTRACT. Eight of 12 species of bats naturally occurring in Indiana were caught on Crane Division, Naval Surface Warfare Center: 161 northern myotis (*Myotis septentirionalis*), 147 red bats (*Lasiurus borealis*), 123 eastern pipistrelles (*Pipistrellus subflavus*), 78 big brown bats (*Eptesicus fuscus*), 22 little brown myotis (*Myotis lucifugus*), 14 hoary bats (*Lasiurus cinereus*), 8 Indiana myotis (*Myotis sodalis*), and 3 silver-haired bats (*Lasionycteris noctivagans*). Evidence of reproduction was obtained for all but the silver-haired bat. Rates of capture were more similar to those in the Hoosier National Forest, also in southern Indiana, than to northern Indiana. A juvenile Indiana myotis was the first record of the species from Martin County. No winter hibernacula or summer maternity colonies of the Indiana myotis were found. The northern myotis was not found in caves but was the most frequently caught species in summer 1998. Two maternity colonies of little brown myotis and a colony of big brown bats were found. The eastern pipistrelle was the most common species in caves and the second most commonly captured species in summer. The red bat was the most frequently caught species in the summers of 1987 and 1996. All species but the big brown bat, a beetle specialist, fed heavily on moths. Several species ate Asiatic oak weevils (*Cyrtepistomus castaneus*), a forest pest.

Keywords: Bats, food habits, habitat, Indiana myotis, *Myotis sodalis*, NSWC Crane, radiotelemetry

To comply with requirements of the Endangered Species Act, studies are conducted on many public properties to determine whether the federally-protected Indiana myotis, *Myotis sodalis*, is present and to learn about its ecological requirements. In 1987, 1996, and 1998 studies were conducted at the Crane Division, Naval Surface Warfare Center (NSWC), a 25,400 ha tract in the Crawford Upland of southwestern Indiana, in portions of Martin, Greene, Daviess, and Lawrence counties, Indiana. This paper presents information from those studies for all species of bats.

In winter, the Indiana myotis hibernates in caves and sometimes mines; but in summer, it forms maternity colonies under the exfoliating bark of dead and dying trees. Therefore, studies of this species entail winter cave searches and summer netting in wooded habitats. Winter use of Indiana's caves was known long before discovery of the first nursery colony (Cope et al. 1974), where Humphrey et al. (1977), reported that females and young used riparian habitat to the exclusion of other habitats. Aquatic-based prey was a large part of the diet (Belwood 1979). In contrast, males in Missouri foraged predominantly in upland woods (LaVal et al. 1977) and ate terrestrial-based prey (Brack & LaVal 1985). In northern Indiana, female Indiana myotis were caught in both upland and riparian habitats (Brack 1983). The Indiana myotis has since been found in a variety of woodland settings across a wide geographic area. Maternity colonies often use several roosts in the same area (Kurta et al. 1993).

At least seven other species of bats are found in southwestern Indiana in habitats they may share with the Indiana myotis. The northern myotis (*Myotis septentirionalis*), little brown myotis (*Myotis lucifugus*), eastern pipistrelle, (*Pipistrellus subflavus*), and big brown bat (*Eptesicus fuscus*) are year-round residents in Indiana. Under natural conditions, they roost in woodlands in summer and hibernate in caves in winter. The little brown myotis and big brown bat frequently roost in buildings in summer, while the northern myotis and eastern pipistrelle occasionally roost in buildings. The big brown bat often hiber-

Figure 1.—Location of Crane Division, Naval Surface Warfare Center, a 25,400 ha tract in portions of Martin, Greene, Daviess, and Lawrence counties in Indiana.

nates in buildings (Whitaker & Gummer 1992, 2000), and all sometimes hibernate in mines.

The red bat, *Lasiurus borealis*, is the second most abundant bat in Indiana during summer, while the hoary bat, *Lasiurus cinereus*, is uncommon. Both species roost in the foliage of trees and migrate south for winter, although the red bat apparently hibernates in northern portions of the wintering range (as far north as central Indiana), but not in caves or mines. The silver-haired bat (*Lasionycteris noctivagans*) migrates through Indiana in spring and autumn but is absent in summer. An occasional individual hibernates in caves in the state (Brack et al. 2003).

METHODS

Study area.—NSWC is in southwestern Indiana and includes portions of Martin, Greene, Daviess, and Lawrence counties (Fig. 1). It covers approximately 25,400 ha and lies largely within the Crawford Upland, a part of the Shawnee Hills physiographic region. The Crawford Upland is characterized by generally flat-topped but narrow drainage divides and steep valleys that generally have moderately wide floodplains. NSWC is south of the Wisconsinan glacial limit, and although not covered by the preceding Illinoian glacier, the area to the west was covered by this earlier glacier. The area is 82% wooded, 15% fields, and 3% bottomlands and stream valleys. The area's original vegetation was predominantly upland oak forests in the west, and mixed mesophytic forests in the east. Present-day vegetation is second growth forest and fields of various successional stages. Upland woods vary in species composition depending upon exposure, soil type and moisture, and other edaphic conditions. Bottomland forests generally contain a characteristic complement of riparian species. In all areas, length of time since last disturbance and degree of disturbance contribute significantly to the existing species complement, community character, and woodland structure.

Bat capture.—In 1987, 3 July–1 August, 30 sites were netted. Mist nets were placed over streams and rivers (5.5–18 m long) and stacked above one another (6–13 m) to sample bats from tree crown to stream surface. Most sites were netted for two nights, dusk to dawn, resulting in 59 net nights of effort. In 1996, 10 sites were surveyed one night each with a single net, typically two tiers high (5 m), for 4–5 h, beginning at dusk.

Netting was also conducted in 1998 (BHE 1999), when 59 sites were netted, and those data were re-analyzed and included here. Each site typically consisted of four net nights, or two nets each run for two nights for 5 h from dusk to about 0200 h. One upland site was run for four nights, resulting in a total effort of 240 net nights. In addition, 48 partial net-nights of effort were completed when surveys were terminated before 0200 h because of adverse weather. Two nets at a site were generally $>$ 30 m apart, 6–9 m high, and 5.5–18 m long. Net sites were in four types of habitats: bottomland hardwoods (n = 144 net nights), mixed hardwoods (n = 60 net nights), oak-hickory woods (n = 28 net nights), and mixed evergreen-hardwoods (n = 8 net nights). Six sites were non-riparian and 53 sites were along stream corridors.

Weight, sex, age, and reproductive condition of bats, and capture time were recorded. Reproductive females (pregnant, lactating, or post-lactating) or juveniles provided evidence of reproduction. Capture was examined by rate of catch per site, rate of catch per net night, habitat of capture (riparian versus non-riparian and four habitat types), and by species diversity. MacArthur's (1972) diversity index was used: Species Diversity Index = $1/\Sigma P_i^2$, where P_i is the proportion of bats in species "i." In 1987, activity during four periods of the night (dusk–2200 h, 2200–2400 h, 2400–0200 h, and 0200 h–dawn) was analyzed with chi-square tests. Chi-square analysis was also used to compare capture between riparian and non-riparian sites (weighted by number of net nights), and between adult males and reproductive females.

In summer 1987, some bridges and buildings were searched for bats, and a bat trap was used to catch bats exiting a building used as a roost. In August 2003, bridges and other structures were searched for bats.

Radiotelemetry.—In 1998, a radiotransmitter (Wildlife materials Model SOPB-201) was attached to a pregnant female Indiana myotis that was followed to a day roost using Wildlife Materials, Inc. receivers (TRX 2000) and 3-element, hand-held Yagi antenna. Four nights of activity were also recorded. The roost tree and nearby habitat were characterized, and six dusk emergence counts were made between 3 June and 2 July 1998. To determine an activity area, triangulation (coordinated with two-way radios) was completed at 5 min intervals. TelemPC (January 1989 version; Method O) was used to determine the activity area based on a 95% minimum convex polygon.

Food habits.—During 1987, feces from 97 bats of 7 species were collected by placing bats removed from mist nets into cloth bags. Guano from each bat was treated as a single sample to avoid bias based on numbers of pellets, because fecal pellets from one bat are often more similar to each other than to pellets from other bats. Foods were identified and percent volume estimated visually for each sample. Data were summarized by percent volume (volume for each food/total volume × 100; Whitaker 1988). One-way ANOVAs with Student-Newman-Keuls multiple range tests using arcsine transformed data were used to test for significant differences between foods eaten.

Hibernacula.—The suitability of known caves on NSWC as hibernacula for the Indiana myotis was determined from a summer 1987 visit to assess geomorphic characteristics that contribute to an influx of cold winter air, and a visit on 28 January 1989 to Aunt Liz and Granny's caves to look for hibernating bats.

RESULTS AND DISCUSSION

Bat capture.—During three summers of netting (1987, 1996, and 1998), 556 bats of 8 species were caught in mist nets: 161 northern myotis, 147 red bats, 123 eastern pipistrelles, 78 big brown bats, 22 little brown myotis, 14 hoary bats, 8 Indiana myotis, and 3 silver-haired bats. Thus, 8 of 12 species of bats naturally occurring in Indiana were caught on NSWC. The red bat was most frequently caught in 1987 (Table 1) and 1996, while the northern myotis was most frequently caught in 1998 (Table 2). Silver-haired bats were caught only in 1998, and hoary bats only in 1987 and 1998. Evidence of reproduction was obtained for all species except the silver-haired bat. In Hoosier National Forest (HNF), also in southern Indiana, the relative abundance of species was similar (Brack et al. 2004), although two additional species, the evening bat (*Nyctiecius humeralis*) and gray myotis (*Myotis grisescens*), were also caught.

Collectively, the catch of bats in mist nets was 1.8 bats/net night and 5.6 bats/net site. In 1987, the rate of catch at individual net sites was 0–13 bats ($\bar{x}$ = 4.3; SD = 2.9) and 0.0–6.5 bats per net night ($\bar{x}$ = 2.2). In 1996, catch per net site and per net night were 3.6 bats (SD = 2.6). In 1998, bat catch was 0.0–5.0 bats per net night ($\bar{x}$ = 1.6; $\bar{x}$ = 1.5 exclusive of rain nights) and 0–20 bats per net site ($\bar{x}$ = 6.6; SD = 4.6). Six net nights (6.1%), two in 1987 (6.7%), one in 1996 (10.0%), and three in 1998 (5.1%), failed to catch bats. In HNF, the rate of catch was 3.3 bats per net night in 1990 and 1.4 bats in 1998 (Brack et al. 2004), and in northern Indiana, Brack (1983) caught 3.4 bats per net night (Table 3).

Collectively, the number of species caught per site was 2.6 (SD = 1.4) and the species diversity index was 4.4. In 1987 the mean number of species per net site was 2.4, the most species caught at any site was eight, and

Table 1.—Numbers of bats caught, catch per net night, and chi-square analysis of catch by time during four periods dusk to dawn during 59 net nights at 30 riparian net sites on the Naval Surface Warfare Center at Crane, Indiana, in 1987.

Bat species	Total	Time periods				χ^2	P
		Catch/ net night	Dusk–2200 h	2200–2400 h	2400–0200 h	0200 h–dawn	
M. sodalis	1	0.02	1	0	0	0	
M. septentrionalis	10	0.17	5	1	2	2	
M. lucifugus	11	0.19	1	5	2	3	
P. subflavus	28	0.47	5	6	4	13	7.1429	0.0675
E. fuscus	19	0.32	9	2	6	2	
L. borealis	53	0.90	12	16	10	15	1.7170	0.6332
L. cinereus	8	0.14	2	1	2	3	
Total	130	2.20	35	31	26	38	2.4923	0.4767

the species diversity index was 4.0. In 1996, the mean number of species per net site was 1.9, the most species caught at any site was four, and the species diversity index was 3.0. In 1998, six species were caught at two sites ($\bar{x}$ = 2.8 species), and the species diversity index was 3.9. Species diversities were similar to those in HNF: 3.4 in 1990 and 3.5 in 1998, and 4.6 collectively (Brack et al. 2004).

Red bats were caught at the most net sites (68.7%), including 21 sites in 1987, 7 sites in 1996, and 40 sites in 1998. However, in 1998, northern myotis were caught at more sites (n = 44). Eastern pipistrelles were caught at 58 sites (58.6%), northern myotis at 53 sites (53.5%), big brown bats at 42 sites (42.4%), little brown myotis at 15 sites (15.2%), hoary bats at 10 sites (10.1%), Indiana myotis at 7 sites (7.1%), and silver-haired bats at 3 sites (3.0%).

The combined capture of all species on NSWC was spread across the night during four periods dusk to dawn (χ^2 = 2.4923, P > 0.4767; Table 1). Capture was significantly greater in riparian than upland habitats (χ^2 = 9.9712, P = 0.0016; Table 2) and was concentrated in the subcanopy foliage layer (χ^2 = 106.0930, P < 0.0000). Bats were caught at a rate of 1.8 bats per net night in bottomland hardwoods, 1.7 in mixed hardwoods, 1.3 in oak-hickory woods, and 0.6 in mixed evergreen-hardwoods. The catch was greater than expected in bottomland hardwoods, and less than expected in oak-hickory and mixed evergreen-hardwoods (χ^2 = 1.3129, P = 0.0366).

Food habits.—Food habits were documented for most species captured (Table 4). Although samples were small, significant differences among species were found. All spe-

Table 2.—Numbers and percent of bats caught and chi-square analysis of catch (weighted by numbers of net nights; 216 riparian and 24 non riparian) at 53 riparian and 6 non-riparian net sites on the Naval Surface Warfare Center at Crane, Indiana, in 1998.

Species	Riparian		Non-riparian		χ^2	P
	Number	%	Number	%		
M. sodalis	6	1.6	0	0.0		
M. septentrionalis	139	37.4	11	57.9	1.0062	0.3158
M. lucifugus	8	2.2	0	0.0		
P. subflavus	80	21.5	2	10.5	4.6286	0.0314
E. fuscus	54	14.5	3	15.8	1.2296	0.2675
L. borealis	76	20.4	3	15.8	2.9623	0.0852
L. cinereus	6	1.6	0	0.0		
L. noctivagans	3	0.8	0	0.0		
Total	372	100.0	19	100.0	9.9712	0.0016

Table 3.—Catch per net night at 53 riparian (Rip), 6 non-riparian (Non-rip), and all net sites (Total) on the Naval Surface Warfare Center at Crane, Indiana, in 1998, and for comparison, rates of catch in the Hoosier National Forest (HNF) in 1990 (26 riparian and 24 upland sites) and 1998 (22 riparian and 12 upland sites; Brack et al. 2004), and at 61 riparian and 89 non-riparian net sites predominately in northern Indiana (Brack 1983).

	Crane			HNF: 1990/1998			Northern Indiana		
Bat species	Rip	Non-rip	Total	Rip	Non-rip	Total	Rip	Non-rip	Total
M. sodalis	0.03	0.00	0.03	0.04/0.03	0.00/0.02	0.02/0.03	0.36	0.12	0.22
M. septentrionalis	0.64	0.46	0.63	0.23/0.49	0.08/0.83	0.16/0.60	0.03	0.26	0.17
M. lucifugus	0.04	0.00	0.03	0.50/0.05	0.00/0.00	0.26/0.03	0.82	0.09	0.39
P. subflavus	0.37	0.08	0.34	2.54/0.38	0.04/0.04	1.34/0.26	0.18	0.0	0.07
E. fuscus	0.25	0.13	0.24	0.65/0.16	0.21/0.02	0.44/0.11	1.80	1.65	1.71
L. borealis	0.35	0.13	0.33	1.81/0.43	0.25/0.24	1.06/0.37	0.92	0.40	0.61
L. cinereus	0.03	0.00	0.03	0.04/0.00	0.00/0.00	0.02/0.00	0.08	0.15	0.12
L. noctivagans	0.01	0.00	0.01	0.00/0.01	0.00/0.00	0.00/0.01	0.0	0.02	0.01
Total	1.72	0.79	1.63	5.81/1.57	0.58/1.55	3.30/1.43	4.39	2.75	3.41

cies except the big brown bat fed heavily (≥ 27%) on lepidopterans. The big brown bat, considered a beetle feeder, ate significantly more insects from the Family Carabidae than did other species ($\alpha = 0.05$). However, the red bat ate more Asiatic oak weevils (*Cyrtepistomus castaneus*; Family Curculionidae), 29.5% by volume, than did other species, including the big brown bat. The weevil is a relatively small food item (6 mm long) for the big brown bat. Many species of bats consume Asiatic oak weevils when they are common (Brack 1983). The eastern pipistrelle was the only species that ate cicadellids (Order Homoptera); the northern myotis was the only species that ate spiders.

Indiana myotis.—This federally-endangered species is a summer resident of NSWC. A juvenile female captured in 1987 was the first record of the species from Martin County, which was followed by capture of an adult male in 1996. Five adult males and an adult female were caught in 1998 in wooded riparian corridors.

During summer, adult male Indiana myotis typically roost singly and often switch use among a variety of roost trees (Brack et al. 2004; Gumbert 2001). Males tend to remain geographically close to winter hibernacula during summer (Whitaker & Brack 2002), and hibernacula are known from Greene, Lawrence, and Monroe counties (Brack et al. 2003). The rate of capture per net night was less than in northern Indiana, but similar to HNF (Table 3). All captured Indiana myotis in HNF were adult males. These data support the hypothesis that maternity colonies of Indiana myotis are more common in northern Indiana.

The Indiana myotis was not found during winter cave surveys. This species hibernates in cold, but not freezing, caves and mines, in areas were the average temperature during the coldest part of the winter is 6–8° C and relatively stable (Brack et al. 2003). Caves visited on NSWC did not provide this environment.

Feces were collected from a single juvenile Indiana myotis, which ate insects belonging to five orders (Table 4). The Asiatic oak weevil was 16.5% of the diet. Brack & LaVal (1985) called the Indiana myotis a selective opportunist that often eats similar types of prey when readily available. Components of the diet vary by habitat, geographic location, season, and sex or age of the bat (Kurta & Whitaker 1998; Brack & LaVal 1985; Brack 1983; Belwood 1979). In Missouri, the proportion of aquatic insects eaten (dipterans, trichopterans, and plecopterans) was small but influenced by the lunar cycle (Brack & LaVal 1985).

On 2 June 1998, an adult female Indiana myotis was radio-tracked to a dead American elm (*Ulmus americana*) in a bottomland hardwood forest inundated by 0.3–1 m of water. The tree was 0.48 km from the capture site and 1.0 km from the center of the bat's active area. The tree was 30.2 cm dbh and trees in a 0.04 ha circle centered on the roost tree had a dbh of 14.2 cm. The tree was smaller than most trees (> 50.8 cm) that host a maternity

Table 4.—Food habits, by percent volume, of seven species of bats caught on the Naval Surface Warfare Center at Crane, Indiana.

Insect group	Indiana $n = 1$	Northern $n = 10$	Little brown $n = 11$	Pipistrelle $n = 19$	Big brown $n = 18$	Red $n = 34$	Hoary $n = 4$
Lepidoptera	29.5	60.5	37.0	27.1	1.9	50.9	30.0
Coleoptera	42.0	2.5	14.1	23.2	1.1	2.7	2.5
Curculionidae	21.5	2.5	27.7	8.4	13.9	29.5	
Carabidae		1.5		1.3	31.4	1.5	22.5
Calathus		3.0					
Scarabaeidae		5.5			20.6	11.2	
Chrysomelidae							
Diabrotica			5.3		8.3	0.1	
Diptera	4.0	0.0	1.4	20.0		0.6	
Tipulidae						0.1	
Chironomidae				5.3			
Trichoptera	1.0		10.5		1.4		
Hymenoptera	2.0						
Ichneumonidae		1.0					
Formicidae				0.3			
Cynipoidea			0.5				
Neuroptera							
Hemerobiidae						0.1	
Hemiptera		0.5	1.4				
Pentatomidae (green)					18.3	2.1	43.8
Pentatomidae (brown)		1.0			2.5		
Lygaeidae		0.0				0.7	
Cydnidae		1.0				0.0	
Homoptera							
Cicadellidae				14.5			
Cercopidae							1.3
Orthoptera							
Gryllidae					0.6	0.3	
Araneae		21.0					
unidentified insect			2.3				
grass seed						0.3	
Total	100.0	100	100.2	100.1	100.0	100.1	100.1

colony (Callahan et al. 1997; Kurta et al. 1993). Dominant species in the stand included red maple (*Acer rubrum*), river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), and oak (*Quercus*) species. Canopy closure was about 45%. Many trees in the stand were dead or dying. The roost tree had 98% of it bark, but 50% was exfoliating. The roost tree was 133 m from a two-lane paved road. On 8 and 10 June, only the bat with a transmitter exited the roost. On 3 June, this bat and a second bat exited the roost. No bats left the roosts on 4 June, 17 June, and 2 July.

The 95% minimum convex polygon (MCP) for this Indiana myotis was 194 ha. Habitat in the 95% MCP included bottomland hardwoods (50.8 ha), mixed hardwoods (57.5 ha), oak-hickory woods (51.2 ha), and water (44.6 ha; a reservoir). Timber stands were primarily pole (10.2–37.8 cm) and saw (> 37.8 cm) timber. Of the 149 points generated with telemetry, 30.8% were in bottomland hardwoods, 41.6% were in mixed hardwoods, 17.5% were in oak-hickory woods, and 10.1% were over water.

In HNF (Brack et al. 2004), also in southern Indiana, five male Indiana myotis were tracked to 14 day-roosts in five species of trees: American elm, shagbark hickory (*Carya ovata*), pine (*Pinus* sp.), northern red oak (*Q. rubra*), and white oak (*Q. alba*). Those roost

trees were 20.3–71.9 cm dbh, retained about 75% of their bark, were in locations with a mean canopy closure of about 50%, and were located in both riparian and upland habitats. In HNF, four male Indiana myotis had 95% MCP active areas of 33.3–226.1 ha that included wooded and open lands in riparian and upland areas. In that study, one bat's active area included a gravel road, another bat a two-lane state highway, and a third bat's active area included a state highway and a divided, four-lane interstate highway; a roost tree was adjacent to the cleared right-of-way of the interstate.

Northern myotis.—The northern myotis was not found hibernating on NSWC, but it was common in summer. In winter, this bat is infrequently found (Brack et al. 2003), apparently because it often hibernates individually in small cracks and crevices in warmer portions of caves (Whitaker & Rissler 1992). Summer maternity colonies are usually under sloughing bark or in cracks of trees.

During summer netting, this species was active throughout the night, as in northern Indiana (Brack & Whitaker 2001). LaVal et al. (1977) and Brack (1983) reported this species forages in the subcanopy foliage layer, and although our catch was greatest in the subcanopy layer, it was too small to test. In contrast to northern Indiana (Brack 1983), but similar to HNF, capture of this bat was not statistically more frequent in upland habitats (Table 2). The rate of capture per net night was greater than in northern Indiana, but similar to that in HNF (Table 3). Although Whitaker et al. (2002) thought abundance of this species was stable over time, the rate of catch increased from 1990 to 1998 in this study and from 1987 to 1998 in HNF. In NSWC, numbers of adult males captured during summer netting were significantly greater than numbers of reproductive females ($\chi^2 = 4.2517$; $P = 0.0392$), although there was no difference between sexes in HNF (Brack et al. 2004). A male adult northern myotis was found day-roosting under a bridge, out of the sun but in full daylight.

The diet of the northern myotis is indicative of a gleaner (Brack & Whitaker 2001). Spiders, the second most important food in the diet of 10 individuals from NSWC (Table 4), were likely consumed while gleaning. We suspect some or many moths eaten were also gleaned. In Missouri and Indiana, lepidopterans were most important in the diet, followed by coleopterans, trichopterans, and dipterans (Brack & Whitaker 2001).

Little brown myotis.—The little brown myotis has a large distribution, and in the eastern part of its range it often roosts in buildings, as it did on NSWC. A maternity colony of little brown myotis inhabited a building sampled on 31 July 1987 when 563 individuals, predominately adult females and juveniles, were caught. In August 2003, a bathhouse on Lake Greenwood contained 100–200 bats of the genus *Myotis*, probably little brown myotis.

In some parts of the range, such as the northeastern United States, little brown myotis are very common. However, in natural habitats of much of the rest of its range, it is often less common. It is sometime considered to be more common along streams and near bodies of water. This was true in southern Indiana in HNF (Brack et al. 2004), and although the catch on NSWC was greatest in riparian habitat, it was too small to test for statistical significance (Table 2). Similarly, catch was greatest in the subcanopy foliage layer, as it was in northern Indiana (Brack 1985), but was too small to test. The rate of capture was much less than in northern Indiana, while the rate in HNF was more variable (Table 3). Catch of adult males during summer netting was significantly greater than catch of reproductive females ($\chi^2 = 9.9412$; $P = 0.0016$), although no such disparity was apparent in HNF (Brack et al. 2004).

One little brown myotis was found in each of the two caves visited during winter. These caves were warmer than typical hibernacula of the species; in Aunt Liz Cave a little brown myotis was hibernating at 12.4° C and the individual in Granny's Cave was in the twilight area below the entrance pit at a temperature of 10.8° C, although this area is probably subject to large temperature fluctuations. Large concentrations of little brown myotis are typically found in cold, anterior portions of caves. However, individuals and small clusters often use warmer areas (Brack et al. 2003).

The little brown myotis exhibits a great deal of variation in its diet, but is loosely described as a dipteran-lepidopteran-coleopteran feeder (Belwood & Fenton 1976; Buchler 1976; Anthony & Kunz 1977). Diets of 11 individuals

were dominated by insects from three orders (Lepidoptera, Coleoptera, and Trichoptera; Table 4). The spotted cucumber beetle (*Diabrotica undecimpunctata*; Order Coleoptera, Family Chrysomelidae) was 5.3% of the diet. Few dipterans, which are often common near water resources, were eaten.

Eastern pipistrelle.—In NSWC, this bat was the second most commonly captured species during summer, and it was the most commonly found species in caves visited. This species sometimes forms small maternity colonies in buildings, but most colonies are located in clusters of dead or living leaves (Veilleux et al. 2003). Proximity of summer and winter habitat is apparently necessary. In Indiana, the species is uncommon north of the Wisconsin glacial limit (Brack & Mumford 1984), where caves and other hibernacula are uncommon.

As in northern Indiana (Brack 1983), the species was caught most frequently in the subcanopy foliage layer (χ^2 = 26.0000, $P <$ 0.0000), and like northern Indiana and HNF, in riparian habitat (Table 2). In Missouri, the species foraged over or near streams (LaVal et al. 1877). Adult males were captured during summer netting significantly more often than reproductive females (χ^2 = 43.8348; $P <$ 0.0000), similar to HNF (Brack et al. 2004). The catch of eastern pipistrelles was similar throughout the night (Table 1). The rate of capture was much greater than in northern Indiana, but within the range noted in HNF (Table 3).

The eastern pipistrelle was found in both caves visited. This species hibernates at a wider range of temperatures than many species, and more frequently at warmer temperatures (Brack & Twente 1985). It is often the only species that hibernates in small caves, and therefore is found in more caves than any other species in Indiana (Brack et al. 2003). Aunt Liz Cave contained 41 eastern pipistrelles. Cave temperatures were 9.4–12.4° C; eastern pipistrelles hibernated in areas that were 10.4–12.4° C. In Granny's Cave, 14 eastern pipistrelles were found in the twilight area below the entrance pit with a temperature of 10.8° C. It is likely the temperature in this area varies greatly over time.

The diets of 19 eastern pipistrelles from NSWC were comprised of insects from four orders (Lepidoptera, Coleoptera, Diptera, and Homoptera; Table 3). Asiatic oak weevils were 8.4% of the volume. Also in Indiana, Brack (1985) found dipterans, trichopterans, coleopterans (including the Asiatic oak weevil), lepidopterans, homopterans, hymenopterans, neuropterans, and plecopterans represented, in decreasing order of importance, in the diet of this species. In Missouri, trichopterans dominated the diet (LaVal & LaVal 1980).

Big brown bat.—Like the little brown myotis, this species has a wide distribution and is locally abundant. It is the most common bat in Indiana. It usually roosts in buildings. In August 2003, about 40 big brown bats were found roosting under a bridge; 20 individuals were captured and most were reproductive females and juveniles, typical of a maternity colony. As in northern Indiana (Brack 1985), the big brown bat frequented both riparian and upland habitats (Table 2), and catch was concentrated in the subcanopy foliage layer (χ^2 = 18.1053, P = 0.0001). Although catch of adult males and reproductive females was similar (χ^2 = 1.6667; P = 0.1967), males were more common in HNF (Brack et al. 2004). The rate of capture was much less than in northern Indiana, but was within the range in HNF (Table 3).

Although the big brown bat is found in caves and mines in autumn, winter, and spring, it was not found in caves on NSWC. Numbers of individuals in caves typically are small because many individuals hibernate in buildings (Whitaker & Gummer 1992, 2000). Individual bats typically use different buildings in summer and winter.

The big brown bat is a beetle feeder, and 75.3% of the diet of 18 individuals from NSWC was beetles (Table 4), including Asiatic oak weevils (13.9%), and spotted cucumber beetles (8.3%). A green Pentatomidae (Order Hemipterans) was 18.3% of the diet. The big brown bat feeds heavily on agricultural pest insects (Whitaker 1995). Foods of the big brown bat from the wooded interior of NSWC were similar to foods in agricultural areas in other parts of Indiana (Whitaker & Weeks 2001). In that study, important foods included beetles (Scarabaeidae, Chrysomelidae – spotted cucumber beetle, Carabidae, and unidentified Coleoptera), hemipterans (a green Pentatomidae – stinkbug, *Acrosternon hilare*), hymenopterans (Formicidae and Ichneumoni-

dae), homopterans (Cicadellidae), and lepidopterans.

Red bat.—The red bat is an abundant summer resident of Indiana, common in a variety of woodland habitats. It is a seasonal migrant; but some individuals apparently remain in the state during winter, although individuals may not be year-round residents. Catch of adult males was similar to catch of reproductive females ($\chi^2 = 1.4118$; $P = 0.0956$), unlike HNF, where reproductive females were more common (Brack et al. 2004). Unlike HNF, the catch of red bats on NSWC was not concentrated in riparian habitat (Table 2). The rate of capture was less than in northern Indiana, and similar to, but less than in HNF (Table 3). On NSWC Crane, as in northern Indiana (Brack 1985), catch was concentrated in the subcanopy foliage layer ($\chi^2 = 37.4231$, $P < 0.0000$).

Red bats feed on a variety of insects (Brack 1985; Whitaker 1972), but moths often form much of the diet (Whitaker et al. 1997). On NSWC, moths were 50.9% of foods eaten by 34 red bats, followed by Asiatic oak weevils (29.5%) and scarab beetles (11.2%; Table 4).

Hoary bat.—This summer resident is not common anywhere in Indiana. Neither in this study, nor HNF (Brack et al. 2004), nor in northern Indiana (Brack 1985) was the catch demonstrably higher in either riparian or nonriparian habitats. The rate of capture was more similar to HNF than to northern Indiana (Table 3).

Fecal pellets from four hoary bats contained both hard-bodied (hemipterans and coleopterans) and soft-bodied (lepidopterans) insects (Table 4). Early studies considered the hoary bat a moth specialist (Black 1972), although moths were not the most common food in Indiana, where one adult female ate only hymenopterans, six juveniles each ate > 90% coleopterans, and two juveniles consumed predominately moths (Brack 1985).

Silver-haired bat.—This was the least frequently caught bat during this study, similar to studies in HNF and northern Indiana. The highest rate of catch in any of these studies was 0.02 bats per net night (Table 3). This is because the species is a seasonal migrant through the area and is absent during summer. All three silver-haired bats were caught in riparian habitat.

ACKNOWLEDGMENTS

NSWC supported field studies in 1987 (through the Indiana Department of Natural Resources; IDNR) and 1998. IDNR supported 1996 (southwest bottoms) studies. We thank the individuals who provided field assistance, S. Andrews, current Natural Resources Manager, NSWC for his assistance and manuscript review, and L. Andrews, Natural Resources Manager during 1987 studies. A. King, U.S. Fish and Wildlife Service, contributed to our understanding of 1998 data. Harmon Weeks and an anonymous reviewer improved the manuscript. This paper is dedicated in memory of Dean Metter.

LITERATURE CITED

Anthony, E.L.P. & T.H. Kunz. 1977. Feeding strategies of the little brown bat, *Myotis lucifugus*, in southern New Hampshire. Ecology 58:775–786.

Belwood, J.J. 1979. Feeding ecology of an Indiana bat community with emphasis on the endangered Indiana bat, *Myotis sodalis*. M.S. thesis, University of Florida, Gainesville. 103 pp.

Belwood, J.J. & M.B. Fenton. 1976. Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 54: 1674–1678.

BHE (BHE Environmental, 3DE Group). 1999. Mist net and radiotelemetry surveys for the Indiana bat at the Crane Division, Naval Surface Warfare Center, Indiana. Unpublished report to NSWC. 39 pp.

Black, H.L. 1972. Differential exploitation of moths by the bats *Eptesicus fuscus* and *Lasiurus cinereus*. Journal of Mammalogy 53:598–601.

Brack, V., Jr. 1983. The nonhibernating ecology of bats in Indiana with emphasis on the endangered Indiana bat, *Myotis sodalis*. Ph.D. dissertation, Purdue University, West Lafayette, Indiana. 280 pp.

Brack, V., Jr. 1985. The foraging ecology of some bats in Indiana. Proceedings of the Indiana Academy of Science 94:231-237.

Brack, V., Jr., S.A. Johnson & R.K. Dunlap. 2003. Wintering populations of bats in Indiana, with emphasis on the endangered Indiana myotis, *Myotis sodalis*. Proceedings of the Indiana Academy of Science 112:61–74.

Brack, V., Jr. & R.K. LaVal. 1985. Food habits of the Indiana bat in Missouri. Journal of Mammalogy 66:308–315.

Brack, V., Jr. & R.E. Mumford. 1984. The distribution of *Pipistrellus subflavus* and the limit of the Wisconsinan glaciation: An interface. American Midland Naturalist 112:397–401.

Brack, V. Jr. & J.O. Whitaker, Jr. 2001. Foods of the northern myotis, *Myotis septentirionalis*,

from Missouri and Indiana, with notes on foraging. Acta Chiropterologica 3:203–210.

Brack, V. Jr., J.O. Whitaker, Jr. & S.E. Pruitt. 2004. Bats of Hoosier National Forest. Proceedings of the Indiana Academy of Science 113:000–000.

Brack, V., Jr. & J.W. Twente. 1985. The duration of the period of hibernation in three species of vespertilionid bats I: Field studies. Canadian Journal Zoology 63:2952–2954.

Buchler, E.R. 1976. Prey selection by *Myotis lucifugus* (Chiroptera: Vespertilionidae). American Midland Naturalist 110:619–628.

Callahan, E.V., R.D. Drobney & R.L. Clawson. 1997. Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri. Journal of Mammalogy 78:818–825.

Cope, J.B., A.R. Richter & R.S. Mills. 1974. A summer concentration of the Indiana bat, *Myotis sodalis*, in Wayne County, Indiana. Proceedings of the Indiana Academy of Science 83:482–484.

Gumbert, M.W. 2001. Seasonal roost tree use by Indiana bats in the Somerset Ranger District of the Daniel Boone National Forest, Kentucky. M.S. thesis, Eastern Kentucky University, Richmond. 136 pp.

Humphrey, S.R., A.R. Richter & J.B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. Journal of Mammalogy 58:334–346.

Kurta, A., D. King, J.A. Teramino, J.M. Stribley & K.J. Williams. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 129:132–138.

Kurta, A. & J.O. Whitaker, Jr. 1998. Diet of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 140:280–286.

LaVal, R.K., R.L. Clawson, M.L. LaVal & W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammalogy 58:592–599.

LaVal, R.K. & M.L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species. Missouri Department of Conservation Terrestrial Series 8:1–53.

MacArthur, R.H. 1972. Geographical Ecology. Harper and Row, New York. 269 pp.

Veilleux, J., J.O. Whitaker, Jr. & S. Veilleux. 2003. Tree roosting ecology of reproductive female eastern pipistrelles, *Pipistrellus subflavus*, in Indiana. Journal of Mammalogy 84:1068–1075.

Whitaker, J.O., Jr. 1972. Food habits of bats from Indiana. Canadian Journal Zoology 50:877–883.

Whitaker, J.O., Jr. 1988. Food habits analysis of insectivorous bats. Pp. 171–189, *In* Ecological and Behavioral Methods for the Study of Bats (T. Kunz, ed.). Smithsonian Institution Press, Washington, D.C. 533 pp.

Whitaker, J.O., Jr. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. American Midland Naturalist 134:346–360.

Whitaker, J.O., Jr. & V. Brack, Jr. 2002. *Myotis sodalis* in Indiana. Pp. 53B-59, *In* The Indiana Bat: Biology and Management of an Endangered Species (A. Kurta & J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Whitaker, J.O., Jr., V. Brack, Jr. & J.B. Cope. 2002. Are bats in Indiana declining? Proceedings of the Indiana Academy of Science 111:95–106.

Whitaker, J.O., Jr. & S.L. Gummer. 1992. Hibernation of the big brown bat, *Eptesicus fuscus*, in buildings. Proceedings of the Indiana Academy of Science 102:133–137.

Whitaker, J.O., Jr. & S.L. Gummer. 2000. Population structure and dynamics of big brown bats, *Eptesicus fuscus*, hibernating in buildings in Indiana. American Midland Naturalist 143:389–396.

Whitaker, J.O., Jr. & L.J. Rissler. 1992. Seasonal activity of bats at Copperhead Cave. Proceedings of the Indiana Academy of Science 101:127–134.

Whitaker, J.O., Jr., R.K. Rose & T.M. Padgett. 1997. Food of the red bat, *Lasiurus borealis*, in winter in the Great Dismal Swamp, North Carolina and Virginia. American Midland Naturalist 137:408–411.

Whitaker, J.O., Jr. & H.P. Weeks, Jr. 2001. Food of *Eptesicus fuscus*, the big brown bat, in Indiana in the absence of cultivated fields and agricultural pests. Proceedings of the Indiana Academy of Science 110:123–125.

Manuscript received 21 November 2003, revised 23 January 2004.