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ARE BATS IN INDIANA DECLINING?

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ABSTRACT. The number of big brown bats in Indiana was estimated using an estimated number of colonies per county times the average number of bats per colony times the number of counties in the state. Estimates of the number of individuals of other species in the state were assessed using their relative abundance by mist-netting in relation to the big brown bat. Assessment of population levels over time was made by examining four decades of submission of specimens to the Indiana Department of Health rabies lab. Twelve species of bats are known from Indiana, of which one, Rafinesque's big-eared bat, *Corynorhinus rafinesquii*, occurs only sporadically and is considered of accidental occurrence. *Myotis austroriparius* was known to hibernate in certain caves in south central Indiana through the early 1970's, but it is apparently now extirpated. This leaves ten species of bats in the state. Two – the gray myotis, *Myotis grisescens*, and the Indiana myotis, *Myotis sodalis* – are on the federally-endangered list. However, there is only one colony of gray myotis in the state. It is in Clark County and has increased from about 400 bats in 1982 to about 4000 today. The Indiana myotis has increased from about 124,000 in 1980 to about 173,000 today, whereas rangewide, that species has declined from about 589,000 in 1980 to 381,000 today. Four other species appear to have declined in Indiana since 1980: the evening bat, red bat, hoary bat and little brown myotis. The big brown bat, eastern pipistrelle, and silver-haired bat may have increased. The northern myotis apparently has remained relatively stable over this period.

Keywords: Bats, Chiroptera, populations, Indiana

The world's human population is increasing rapidly, and consequently natural and agricultural land is rapidly disappearing (at a rate of about 102,000 acres per year in Indiana and and that rate of disappearance is rapidly increasing). These forces tend to make it increasingly difficult for many native species to survive as their habitat becomes both reduced and degraded. We therefore thought it would be of interest to attempt to determine whether the various species of bats of Indiana are declining.

Twelve species of bats are known from Indiana (Mumford & Whitaker 1982), including five species of *Myotis*: the southeastern myotis (*M. austroriparius*), gray myotis (*M. grisescens*), little brown myotis (*M. lucifugus*), northern myotis (*M. septentrionalis*, previously known as *M. keenii*), and Indiana myotis (*M. sodalis*). Other species are the big brown bat (*Eptesicus fuscus*), eastern pipistrelle (*Pipistrellus subflavus*), evening bat (*Nycticeius humeralis*), silver-haired bat (*Lasionycteris noctivagans*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), red bat (*Lasiurus borealis*), and hoary bat (*Lasiurus cinereus*).

Since *Mammals of Indiana* was published (Mumford & Whitaker 1982), many studies have been carried out on bats in Indiana, both on individual species and at the community level, using a number of approaches. The biggest problem in determining bat population trends is that often there are not adequate older data to compare to more recent data. Also, data sets are based on different collection methods. It is difficult to estimate the abundance of most of the species of bats, but some approaches can be used to indicate relative population size.

We have accumulated considerable information on some of the bats, particularly *Myotis lucifugus*, *Myotis grisescens*, *M. septentrionalis*, *Myotis sodalis*, *Eptesicus fuscus*, *Nycticeius humeralis*, and *Pipistrellus subfla-*

[1]*Deceased*

vus. Also much work has been done on certain bat communities, particularly those of Prairie Creek in Vigo County, along the Wabash and Ohio Rivers in southwestern Indiana, and at Copperhead Cave (Vermillion County) by Whitaker and associates. Brack and associates and also Whitaker and associates have carried out extensive netting over streams in much of Indiana to determine distribution and summer habitat of *Myotis sodalis* and other species. These studies have occurred in 80 of the 92 counties throughout the state. Another excellent source of information is the data from the Indiana State Department of Health rabies laboratory, since numerous bats have been received over a long period of time (1966 to present). The rabies lab data give relatively good information for all species. In addition, Brack and associates have carried out surveys in winter for *Myotis sodalis* and other bats present in known and suspected *M. sodalis* hibernacula (plus some newly-added ones) every other year since 1980 in accordance with U.S. Fish & Wildlife Service guidelines. Also data collected by netting or with harp traps at cave or mine entrances are pertinent for some species, and the numbers of colonies in buildings are pertinent for others.

This paper has two objectives: (1) to determine if bats in Indiana are declining, and (2) to provide baseline estimates of the total numbers of bats, by species, in the state. It is recognized that these tasks are difficult. However, despite the difficulties, we offer estimates of the total number of each species present in the state, and determine whether the various species are stable, increasing, or decreasing.

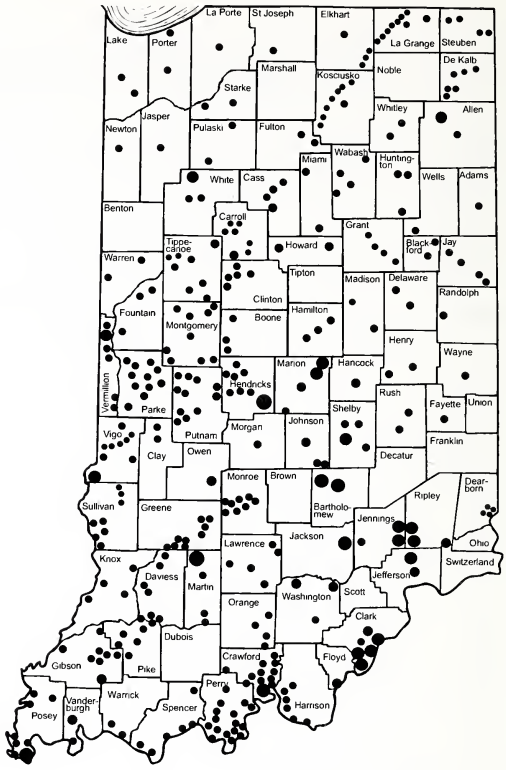

Figure 1.—Mist-netting for bats in Indiana, 1980 to present. Not all sites could be precisely designated. Large dots represent several to many nettings. Small dots sometimes represent more than one site.

METHODS

The data sets.—Only two sets of data (mist-netting and rabies lab) include all species of bats in Indiana. Other methods sample only certain species of bats. Mist-netting along streams or other flyways probably gives the best data for estimating numbers of individuals of each species. However, we do not have enough early (20–30 years ago) mist-netting data to compare with later data (1985 to present) to estimate population changes. Data from bats submitted to the Indiana Department of Health Rabies Laboratory are weighted towards bats that occur in buildings, but we separated the data by decade and thus looked for population trends. Therefore, we used the mist-netting data to estimate the numbers of the various species of bats living in Indiana; and the rabies lab data as our primary source (supplemented by other sources) to estimate population trends in the various species.

We have data from 1067 mist-nettings from throughout the state (Table 1; Fig. 1). Data are included here from 80 of the 92 Indiana counties, and from 6445 bats including all ten species currently known to exist in the state. This sample contains two major biases: oversampling at Prairie Creek in Vigo County, where the evening bat is abundant, and in Clark County where the only gray myotis colony occurs, clearly producing large counts for those two species in those two areas. To correct for this bias we calculated the average number (3.1) of evening bats per netting at Prairie Creek for three rather than the 181 nettings that occurred there [3.1 × 3 samples = 9 rath-

Table 1.—Bats caught in 1067 nettings from throughout Indiana. The estimated numbers here are derived on a proportional basis (ratio) using our big brown bat estimate of 1,111,360 individuals (see text). Data are adjusted downwards for a large number of nettings of *Nycticeius humeralis* in Vigo County, and of gray bats in Clark County by including average number in three samples for those species in those counties.

Species	Number netted	Ratio	Estimated number
Eptesicus fuscus	1748	1.000	1,111,360
Lasiurus borealis	1268	0.725	805,736
Myotis lucifugus	883	0.505	561,237
Pipistrellus subflavus	741	0.424	471,217
Myotis septentrionalis	741	0.424	471,217
Myotis sodalis	246	0.141	156,702
Nycticeius humeralis (658)	105	0.060	66,681
Lasiurus cinereus	70	0.040	44,454
Lasionycteris noctivagans	16	0.009	10,002
Myotis grisescens (74)	12	0.007	7,780
Myotis austroriparius	0	0.000	prob. extirpated
Corynorhinus rafinesquii	0	0.000	accidental
Total	5830		3,706,386

er than 562] and the average of 1.02 gray myotis per netting [1.02 × 3 = 3 rather than 65 gray myotis] for Clark County. These changes gave totals of 105 evening bats and 12 gray myotis, thus reducing the total from 6445 to 5830 bats (Table 1).

Whitaker & Gummer (2000) previously estimated the number of big brown bats in Indiana at 504,000. However, this was a very conservative estimate, and the actual number is clearly higher than that. We currently estimate the number of big brown bats in the state at 151 per colony × 80 colonies per county × 92 counties = 1,111,360. The 1748 big brown bats (Table 1) are 29.9% of the total bats (5830) netted, thus our estimate of 1,111,360 big brown bats represents 29.9% of the total bats in the state. From these data, we can estimate the total number of bats in the state at 3,706,386 (Table 1).

We assumed that bats mist-netted were taken in proportion to their relative abundance, then we estimated the number of bats for each species in the state based on its ratio to big brown bats. Data obtained this way are given in Table 1 listed in order by decreasing abundance of the bats.

The bats submitted to the rabies laboratory (Table 2) favors bats most apt to come into contact with humans (big brown bats and little brown myotis); but all ten species of bat currently living in Indiana were included, and most appear to occur in this sample in reasonable proportion to our overall assessment of their abundance using all sources of data. *Myotis septentrionalis* does appear to be under-

Table 2.—Bats submitted to rabies laboratory by decade, numbers and percent of total (in parentheses).

	1966–1969	1970–1979	1980–1989	1990–2000	Total
Eptesicus fuscus	473 (59.2)	1145 (70.6)	1495 (68.2)	1911 (68.4)	5024 (67.8)
Lasiurus borealis	184 (23.0)	313 (19.3)	428 (19.6)	447 (16.0)	1372 (18.5)
Myotis lucifugus	61 (7.6)	52 (3.2)	103 (4.7)	116 (4.2)	332 (4.5)
Pipistrellus subflavus	18 (2.3)	12 (0.7)	29 (1.3)	180 (6.4)	239 (3.2)
Lasiurus cinereus	30 (3.8)	47 (2.9)	44 (2.0)	51 (1.8)	172 (2.3)
Lasionycteris noctivagans	5 (0.6)	17 (1.0)	45 (2.1)	50 (1.8)	117 (1.6)
Myotis sodalis	15 (1.9)	13 (0.8)	27 (1.2)	21 (0.8)	76 (1.0)
Nycticeius humeralis	10 (1.3)	12 (0.7)	7 (0.3)	9 (0.3)	38 (0.5)
Myotis septentrionalis	3 (0.4)	11 (0.7)	11 (0.5)	8 (0.3)	33 (0.4)
Myotis grisescens	0 (0)	0 (0)	0 (0)	1 (0.04)	1 (0.01)
Total	799	1622	2189	2794	7404

Table 3.—Data on bats from netting as compared to that from the Indiana Department of Health Rabies Laboratory, Indianapolis.

	Netting			Rabies lab		
	Rank	No.	%	Rank	No.	%
Eptesicus fuscus	1	1748	29.9	1	5024	67.8
Lasiurus borealis	2	1268	21.7	2	1372	18.5
Myotis lucifugus	3	883	15.1	3	332	4.5
Pipistrellus subflavus	4	741	12.7	4	239	3.2
Myotis septentrionalis	5	741	12.7	8	33?	0.8
Myotis sodalis	6	246	4.2	7	76	1.0
Nycticeius humeralis	7	105	1.8	9	38	0.5
Lasiurus cinereus	8	70	1.2	5	172	2.3
Lasionycteris noctivagans	9	16	0.3	6	117	1.6
Myotis grisescens	10	12	0.2	10	1	0.01
Total		5830			7404	

represented. Only one gray myotis, taken in 2000, was included. However, this is logical since there is only one gray bat colony in the state and is increasing.

Other data sets give information on some species only. Data on bats hibernating in 52 caves, many of them inhabited in winter by *M. sodalis*, also provide information on *M. lucifugus*, *P. subflavus*, and *E. fuscus*. Data from trapping at cave and mine entrances provide information primarily on *M. lucifugus*, *M. septentrionalis* and *P. subflavus*. Data on bat colonies in buildings give information on *E. fuscus*, *M. lucifugus*, *P. subflavus* and *N. humeralis*.

RESULTS

We used mist-netting data to estimate the total number of each of the 10 species of bats currently existing in the state (Table 1), based on ratios with respect to the big brown bat. In order of decreasing abundance, they are *Eptesicus fuscus*, *Lasiurus borealis*, *Myotis lucifugus*, *M. septentrionalis, Pipistrellus subflavus*, *Myotis sodalis*, *Nycticeius humeralis*, *Lasiurus cinereus*, *Lasionycteris noctivagans*, and *Myotis grisescens*. Note that the estimates for *Myotis septentrionalis* and *Pipistrellus subflavus* are the same. *Myotis austroriparius* is probably extirpated, and *Corynorhinus rafinesquii* is best considered as of accidental or sporadic occurrence from Kentucky rather than as resident.

The best set of data for assessing population trends is that from the rabies lab (Table 2), and includes 7404 bats that have been identified. These numbers by decreasing overall abundance are: *Eptesicus fuscus* – 5024 (67.8%), *Lasiurus borealis* – 1372 (18.5%), *Myotis lucifugus* – 332 (4.5%), *Pipistrellus subflavus* – 239 (3.2%), *Lasiurus cinereus* – 172 (2.3%), *Lasionycteris noctivagans* – 117 (1.6%), *Myotis sodalis* – 76 (1.0%), *Nycticeius humeralis* – 38 (0.5%), *Myotis septentrionalis* – 33 (0.4%), and *Myotis grisescens* – 1 (0.01%). Only one gray myotis was in the rabies lab sample; and it was submitted in 2000, the last year of the study. This is logical, as the only known colony of gray myotis numbered 400 when first discovered in 1982, and has increased to about 4000 by the year 2000. A comparison of percentages of bats from netting and from the rabies lab is given in Table 3. Both sets of data indicate that *Eptesicus fuscus*, *Lasiurus borealis* and *Myotis lucifugus* are the three most abundant species of the state. However, *Eptesicus fuscus* accounts for about ⅔ of the bats in the lab sample, whereas it accounted for about ⅓ in the netting sample. This is explained by the fact that it is the most common house bat, and therefore most likely to be turned in to the rabies lab. The prominence of this species in the rabies sample depresses the percentages of all the other species. One might suppose that the little brown myotis would also be more abundant in the rabies sample than in the netting sample because it is the second most common bat in houses. It was not because it occurs in relatively few buildings as compared to the big brown bat. We found 330 big brown

bat colonies and only 58 little brown myotis colonies in buildings. Also (see below) it may be decreasing in abundance.

There are other notable differences between the netting and samples from the rabies lab. *Myotis septentrionalis* was particularly low in the sample from the rabies lab. The reason for this is difficult to explain as this species is quite common, as indicated by both netting and trapping cave and mine entrances. It would appear that the woodland habitat of this species, plus some behavioral peculiarity, keeps it from being often found by humans.

The occurrence of the silver-haired bat is more numerous in the rabies lab sample. This is because it migrates through Indiana in spring and fall, when less netting takes place. The abundance of the hoary bat in the sample from the rabies lab is somewhat difficult to explain. From netting, it appears to be relatively uncommon, but it may be relatively difficult to net. However, it is more likely that it is much more apt to be seen by people when it is sick and on the ground because it is large and showy.

Although the bats in the sample from the rabies lab occur in different relative proportions than those taken by mist-netting, they can be separated by decade and provide the best sample to determine if there are changes in proportions. Over time, such changes would indicate increases or decreases in relation to other species. Chi-square was used to test for significance, using the total numbers of bats taken in each period to calculate expected values.

It appears that *E. fuscus*, *P. subflavus*, and *L. noctivagans* have significantly increased over the period of the study in relation to the other species (X^2 = 10.78, 11.486, and 11.4 respectively, each with 3 *df*, $P = 0.05$). It appears that *L. borealis*, *L. cinereus*, *M. lucifugus*, and *N. humeralis* have decreased over this period in relation to the other species (X^2 = 20.1, 13.2, 24.5 and 13.7, again each with 3 *df*, $P = 0.05$). There was no evidence of a change in relative abundance to other species in the Indiana and northern myotis (X^2 = 9.4 and 4.7, each with 3 *df*).

Bats hibernating in caves and mines.—Five species of bats regularly hibernate in caves and mines in Indiana: the Indiana myotis, little brown myotis, northern myotis, eastern pipistrelle and big brown bat (Table 4). Data on bats hibernating in 28 caves visited numerous times from 1980 to the present are given in Table 4. These data are from Brack & Dunlap (unpubl. data), who have been conducting cave surveys of hibernating Indiana myotis and recording other species for the past 20 years. Note that little brown myotis and eastern pipistrelles are regularly recorded in many of the caves. However, only one individual of *M. septentrionalis* was recorded during all of this work, although it is common in Indiana, and it is commonly taken during trapping or mist-netting at cave entrances. For example, 291 individuals were trapped during 52 visits to assorted cave and mine entrances in Indiana along with 839 little brown myotis and 386 pipistrelles. Mumford & Whitaker (1982) did not know where *M. septentrionalis* hibernated. However, data collected since 1982, especially at Copperhead Cave in Vermillion County, plus mist-data, indicate that *M. septentrionalis* is seldom found hibernating in caves in Indiana because it nearly always hibernates in deep cracks and crevices (sometimes even in hollow stalactites), and thus is seldom seen (see *M. septentrionalis* account for more information). Of the estimated 1,111,360 big brown bats in the state, only about 15,000–30,000 individuals hibernate in caves and mines. The rest hibernate in buildings (Whitaker & Gummer 1993, 2000). This leaves us with three species of bats, *M. sodalis*, *M. lucifugus*, and *P. subflavus* for which we can get useful information from this source.

Winter cave counts give good estimates of Indiana myotis wintering in the state, as we think we know all major caves and most minor caves in which they hibernate. They are counted every other year and the count has increased from about 148,000 in 1981 to about 173,000 in 2001. Further, the count is fairly similar to the estimate obtained by the ratio of *M. sodalis* to *Eptesicus* during mist-netting, giving some degree of confidence in the netting estimates. The cave estimate applies only to winter, and we have no way of estimating how many of these bats remain in Indiana in the summer. Some probably migrate into Ohio and Illinois, and some form maternity colonies in Michigan. Also, some bats that winter in Kentucky summer in Indiana. Bats banded in Michigan have been

Table 4.—Bats hibernating in (52) caves in Indiana 1980–1999, average number per visit (mostly from Brack & Dunlap 1999). The asterisk (*) indicates a single visit only in 1982.

	No. visits	*Myotis sodalis*	*Myotis lucifugus*	*Eptesicus fuscus*	*Pipistrellus subflavus*
Clark County					
Indian	1	0	0	0	0
Crawford County					
Batwing	10	15,263.5	*1	*0	*11
B-B hole	1	0	156	0	9
Bentz	2	1.5	51	5	28
Easter Pit	1	0	108	0	7
Mellet Pit	1	0	0	0	1
Little Mellet Pit	1	0	0	0	0
Robinson Ladder	6	271.2	55.2	0	10.7
Saltpeter	8	497.6	157.3	7	28.9
Twin Domes	10	74,770	*0	*0	*0
Westerhof	1	0	0	0	3
Wildcat	7	31.7	394.4	0	36.7
Wyandotte	9/10	13,480.8	78.3	22.2	11.9
Greene County					
Ashcraft	3	17	129.7	1.3	6.7
Clyfty	8	298.4	252.1	7.6	99.3
Ray's	11	30,973.1	1,159.4	76	37.5
Sexton Springs	4/5	95.3	71	1.6	23.3
Harrison County					
Binkley's	1	84	197	0	17
Jughole	7	11,232	9.7	8.3	9.9
Little Jug Hole	1	0	1	0	7
Parker's Pit	8/7	1,097.5	186.7	5.6	8.6
Penny Well	1	0	0	0	2
Swinney	2	20	1.5	6.5	0.4
Wallier	5	272.6	3.2	23.6	11.6
Lawrence County					
Bronson's	1	0	0	0	3
Dixon's Pit	1	0	133	5	75

Table 4.—Continued

	No. visits	*Myotis sodalis*	*Myotis lucifugus*	*Eptesicus fuscus*	*Pipistrellus subflavus*
Donaldson's	1	0	0	2.5	3
Donnehue's	2	0	108.5	8.5	8
Hamer's	1	0	1	10	1
King	2	0	0	2	0
Mitchell Crushed Stone	2	20	279	193	52
Salts	2	0	67.5	15.5	30
Sullivan	1	0	0	0	0
Twin	1	0	0	1	0
Martin County					
Aunt Liz	1	0	1	0	41
Granny's	1	0	1	0	14
Monroe County					
Big Windy (Bauer's Blowhole)	1	0	24	0	1
Borden's Pit	1	0	13	0	26
Buckner's	9	143	25.3	2.2	9.6
Coon's	10	3,129.9	235.6	2.8	134.8
Eller's	1	0	0	0	3
Grotto	10	2,922.1	690.1	2.1	24.4
King Blair/Brinegar's	5	416.8	401	0	151.8
Leonard's Spring	6	99	174	0.3	59.7
Ranard School	1	0	0	8	0
Salamander	4	18.8	100	0.3	37.5
Saltpeter	7	131.3	42.6	19.9	9.1
Owen County					
Boone's	1	0	1	10	18
Washington County					
Endless	7	247	569.3	12.9	52.9
Mill	1	0	9	0	74
Panther/Neyman	3	136.3	257.3	3.3	6.7
River	4	28	249	2.5	89.5

found at hibernacula in Indiana and Kentucky (Kurta et al. in press).

The cave counts give less accurate estimates of little brown myotis because not all caves are included, sometimes not even the entire cave in which counts are made. The cave counts were established for *Myotis sodalis*. However, many or most of the more important *Myotis lucifugus* hibernacula are included, and thus they may indicate population trends. *Myotis lucifugus* has been decreasing in Ray's Cave. This is particularly interesting because *Myotis sodalis* had been increasing in Ray's Cave until in 1999 when it harbored the most Indiana myotis of any cave throughout its winter range. (It dropped back into second in 2001.) The only other cave in which *M. lucifugus* might have been declining is Salamander, but there are too few data from Salamander to consider this a trend. In addition, periodic flooding has probably caused some loss of bats there. On the other hand there are three caves (Grotto, Coon and Endless) in which *M. lucifugus* may have been increasing. Indiana myotis may have increased a bit in Endless Cave, but they show little if any change in the other two caves. The only other cave we know of with numbers of either of these species is Copperhead Cave (a mine in Vermillion County) which usually contains about 200 little brown myotis and 100 pipistrelles.

Trapping at cave entrances.—Trapping and mist-netting at cave and mine entrances can give useful information on *Myotis lucifugus*, *M. septentrionalis*, *Myotis sodalis* and *Pipistrellus subflavus*. These three species are the common bats that swarm at cave and mine entrances, and hibernate in caves in Indiana. *Myotis lucifugus* and *M. septentrionalis* can be taken by netting entrances even in winter, *Pipistrellus* is seldom taken in winter. More data are needed, but *Myotis sodalis* appears to be uncommon at entrances except at caves in which it hibernates. Unfortunately, we have no caves or mines where we have extensive earlier and later data on any of these species.

Myotis lucifugus was the most common bat at Copperhead, Zenas, Donnehues and Wyandotte Caves. However, *M. septentrionalis* was most abundant at Panther Cave and was more abundant than *M. lucifugus* in 52 mines netted.

Bats roosting in buildings.—Data on bats roosting in buildings in Indiana are given in Table 5. The bats roosting in buildings in order of decreasing abundance are *E. fuscus*, *M. lucifugus*, *P. subflavus*, *N. humeralis*, and *M. septentrionalis*. Cope et al. (1961) collected information on 188 colonies in 1959; 30 years later Whitaker & Gummer (1993) collected information on 401 colonies. These data provide information on the relative, not absolute, numbers of bat colonies of these species in buildings. During this time the percentage of *E. fuscus* and *P. subflavus* colonies increased, whereas those of *M. lucifugus* and *N. humeralis* decreased. The individual species are discussed below.

Table 5.—Bat colonies in buildings in Indiana in 1989 as compared to 1959.

	Cope 1961 1959		Whitaker 1989	
	No.	%	No.	%
Eptesicus fuscus	142	75.5	330	82.3
Myotis lucifugus	41	21.8	58	14.5
Pipistrellus subflavus	1	0.5	12	2.9
Nycticeius humeralis	4	2.1	1	0.2
Total	188		401	

Southeastern myotis, *Myotis austroriparius*.—Mumford & Whitaker (1982) indicated that this species had decidedly decreased between 1949 and 1982. Most Indiana records are from hibernating individuals in caves. There were about 50 individuals in Bronson's Cave 7 February 1949 (40 were collected on the following day). The largest number recorded after that in Bronson's Cave was 8 on 30 March 1966. A cluster of 25 was found in Donaldson's Cave on 23 November 1951, and about two-thirds of them were banded. Since then, the maximum number seen in that cave was 3, on 6 March 1954. This species regularly hibernated in Donnehue's Cave at Bedford (Lawrence County), through the early 1970's. The number of individuals found there was 9 on 8 January 1954, 19 on 12 February 1955, and 28 on 28 December 1955. Small numbers of this species were found there as well as in a few other caves throughout the early 1970's. Twenty-five individuals were taken at Donnehue's Cave in 20 mist-nettings in 1970–71, mostly in August (10) and September (9). The last verified record of this species was one banded by J.B. Cope in Don-

nehue's Cave on 4 February 1977. This species appears to be extirpated in Indiana.

Gray myotis, *Myotis grisescens*.—Only one gray myotis was submitted to the rabies lab, and only 12 were taken by mist-netting, indicating the low number of gray myotis in Indiana. Only one (or possibly two) colony of this species in Clark County is known from the state. The gray myotis has increased from about 400 individuals in that colony in 1982 to nearly 4000 by the year 2000. Highest estimates for various years are: 1982 (400), 1986 (453), 1988 (253), 1990 (481), 1991 (752), 1994 (1101), 1997 (1949), 1998 (1552), 1999 (1430), 2000 (3768).

Little brown myotis, *Myotis lucifugus*.—Data from the rabies lab indicate a decrease in little brown myotis in relation to big brown bats and pipistrelles. Cope et al. (1991) found that little brown myotis colonies in buildings decreased in relation to big brown bat colonies between 1959 and 1989 (Table 5). *Myotis lucifugus* colonies decreased from 21.8% of the colonies in 1959 to 14.5% in 1989. Big brown bat colonies increased from 75.5% of the colonies in 1959, to 82.3% in 1989. If 82.3% of the colonies in buildings are of *E. fuscus* and if there are 80 big brown colonies per county, then there are about 80 × 92 or 7360 *E. fuscus* colonies in the state. The 58 little brown myotis colonies form 17.6% of the number of big brown bats. Following that logic, there should be about 0.176 × 7360 or 1295 little brown myotis colonies in the state. The average size we derived from 52 little brown myotis colonies (range from 6–6500) was 564, thus our estimate of little brown myotis in the state would be 564 × 1295 or 730,380. This is close to the estimate of 561,237 that we got as the ratio of bats of this species taken by mist-netting. Additional evidence that the little brown myotis has decreased is that besides the changes in proportion, two of the roosts that contained little brown myotis three decades ago now contain big brown bats (Cope et al. 1991). Our data indicate a decrease in little brown myotis in Indiana.

Northern myotis, *Myotis septentrionalis*.—*Myotis septentrionalis* was estimated by mist-netting to be fourth or fifth in relative abundance (total 471,217). Because little is known about its biology it is difficult to assess population trends. It hibernates in caves and mines; but very few individuals can be found, even in caves known to serve as hibernacula. Mumford & Whitaker (1982) stated that although they had found the species hibernating in at least 20 caves, the greatest number of individuals found during one visit was 11 in a cave near Kent (Jefferson County) on 3 January 1959. Usually there were not more than 6 per cave, although numerous bats of this species may be found swarming at certain cave entrances. Whitaker & Rissler (1992) found that *Myotis septentrionalis* apparently hibernates in Copperhead Cave in some numbers, although none have been found there during hibernation. Evidence indicating that Copperhead Cave is a hibernaculum is: (1) the number of northern myotis that enter the cave in fall; (2) the number that emerge in winter and spring; and (3) on relatively warm spring nights, when northern myotis are emerging from the mine, individuals can be found exiting from the cracks. For example, 12 were observed on 15 March 1991. Some of these bats had smears of mud on them, apparently indicating recent emergence from cracks.

Whitaker & Rissler (1992) used trapping data to estimate the number of northern myotis emerging from Copperhead Cave in spring. Sampling times averaged 7.5 h or 62.5% of the dark period at that time of year. To determine if banded bats might be reentering the mine or if bat activity might taper off after our normal sampling period ended, bats were trapped throughout the night on two separate occasions. The results indicated that bat activity continued all night and that individuals seen earlier did not generally return to the mine after our normal sampling period ended. The emergence of northern myotis in 1990 started 9 March and lasted through 17 April, a total of 40 nights. Trapping was done on ten of these nights. The average number of northern myotis taken per night was 22.7 (4.2 bats/0.625 = 22.7 bats; SD = 15.9, SE = 5.3). Based on this number, an estimated 908 northern myotis exited the mine in spring (22.7 bats/night × 40 nights = 908). This figure is a tentative, minimal estimate of the hibernating population there.

Cave and mine netting in fall and other mist-netting data indicate that this species, *M. lucifugus* and *P. subflavus* are relatively similar in number, and that it is probably about the fourth or fifth most abundant bat in the state. Interestingly, very few northern myotis,

M. septentrionalis, totalling only 33, or 0.4%, are submitted to the rabies laboratory. It is not known why so few bats of this species are submitted to the rabies laboratory other than it probably has something to do with its behavior. All other data indicate that the species is remaining reasonably stable in the state.

Indiana myotis, *Myotis sodalis*.—The best data on *M. sodalis* are those currently collected every two years in hibernacula, and the population has increased somewhat during this period. The five caves in Indiana currently serving as primary hibernacula for Indiana myotis are included in Table 4. Overall, numbers of hibernating Indiana myotis have increased in Wyandotte, Jug Hole and especially in Ray's Cave. Ray's Cave had become the most important hibernaculum for *M. sodalis* in its entire range in 1999. However, the number there decreased in 2001, when Twin Domes Cave was again the top hibernaculum for that species in Indiana. However, rangewide, this species appears to be decreasing, especially in Kentucky and Missouri. Suitable temperature (3–7°C) appears to be the single most important factor necessary for the success of hibernating Indiana myotis (Richter et al. 1993), although temperature stability is also important. In Indiana, Indiana myotis have apparently been moving from Batwing and Twin Domes Caves. The temperature in Batwing and Twin Domes Caves may have been increasing (due to global warming?) whereas temperatures in Wyandotte and Ray's Caves have decreased (due to modifications at entrance in Wyandotte allowing cold air in, and due to the increased size of a natural opening of a small upper entrance in Ray's Cave, causing movement of warm air upward and out, and thus pulling cold air in the lower main entrance). Bat numbers have radically increased in these two caves, which has led to the statewide increase.

Big brown bat, *Eptesicus fuscus*.—The best evidence for the big brown bat population trends is the data from the rabies lab and the data on bat colonies in buildings. We estimate that there are about 1,111,360 big brown bats present in Indiana. Assuming a bat to forage out 1.5 miles (2.4 km) in all directions from its colony, we might assume a foraging range of $3 \times 3 = 9$ square miles (23 sq km). Since an average county in Indiana includes about 750 square miles (1920 sq km), then there might be about 80 colonies per county (750/ $9 = 83.3$). Evidence that the big brown bat is increasing is that the number submitted to the rabies lab is increasing proportionately, forming 59% of the total in 1966–69, nearly 70% later (Table 3). This is the bat species most adapted to living alongside man, and is the species most often in structures. We believe that big brown bats are increasing and that they are tending to outcompete little brown (and evening) bats for roosts in buildings. The mist-netting data also show that the big brown bat is the most common bat of the state, although the number taken by netting (1268) is lower than expected. This is probably because big brown bats are most abundant near structures, and most of the samples were along wooded streams rather than near structures.

Eastern pipistrelle, *Pipistrellus subflavus*.—Data from the rabies lab indicates numbers and percentages of this species have been increasing considerably, from 2.3% in 1966–69 to 6.4% in 1990 to 2000 (Table 2). Also, the pipistrelle increased as a percentage of colonies found in buildings, up in 1989 at 2.9% from 0.5% 30 years earlier (Cope et al. 1991). *Pipistrellus subflavus* was estimated by mist-netting along with *M. septentrionalis* to be fourth/fifth in relative abundance.

Evening bat, *Nycticeius humeralis*.—The evening bat was the seventh most abundant bat as estimated by mist-netting (Table 1), with its revised count being 105. All earlier evening bat colonies were found in buildings, but recently we have found evening bats to be abundant in hollow trees in bottomland woods in the Wabash Valley from Vigo to Posey County (but not east in the Ohio River Valley). We think that *Nycticeius* was present all along in this habitat, and that this habitat resembles the original prime habitat for the species at least in the northern part of its range. Further, we suspect that *Eptesicus* and *Nycticeius* may compete for roosts in buildings and that *Eptesicus* has basically won out in this competition in upland areas. For example, 4 among 188 (2.1%) of the bat colonies found in buildings by Cope et al. (1961) were evening bat colonies. The original colonies were all gone by 1993 when only 1 of 401 (0.2%) colonies then was of *Nycticeius*. Because of its loss in buildings and from loss of bottomland woods, we suspect that this species has decreased in Indiana since the 1960's.

Silver-haired bat, *Lasionycteris noctivagans*.—Few silver-haired bats are taken by mist-netting, but most of our netting is after the spring migration and before the fall migration of this species. A relatively large number of specimens are submitted to the rabies lab, 117 over the years, and data from that source indicate that this species is increasing slightly.

Red bat, *Lasiurus borealis*.—The red bat appears to be the second most abundant bat in the state (after the big brown bat), as indicated by both mist-netting and rabies lab data. However, the rabies lab data indicate a decrease in this species relative to other species. From the rabies lab, the numbers of bats submitted continue to increase (indicating increased awareness of bats in the state). However, the percentage of red bats has shown a significant decline from 23.0% of the bats in 1966–69 to 16% in the last decade. We suspect that the decrease in the numbers of red bats is real and is related to continued loss of natural lands, especially woodlands, to development.

Hoary bat, *Lasiurus cinereus*.—The rabies lab data show significant decrease in percentage of hoary bats submitted through time. The hoary bat formed 3.8% of the bats submitted in 1966–69, as compared to 1.8% in the past decade. The decrease in the number of hoary bats, like the red bat, is probably related to continued loss of natural lands, especially woodlands, to development.

Rafinesque's big-eared bat, *Corynorhinus rafinesquii*.—There are only 18 records of this species known in the state. We consider it of accidental occurrence from Kentucky and Illinois. The earliest record of this species in the state was from Putnam County where two individuals were taken in 1894 in a cave near Greencastle (Butler 1895). Otherwise, there are 10 records for the Spring Mill State Park area (1902–1907), five in Washington County (1954–1962), and one in Tippecanoe County (1959). The last verified records of this species in the state had been in 1962 in a cave near Smedley in Washington County. However, a big-eared bat was reported from Squire Boone Cave several times over a period of about a month in the summer of 1992.

DISCUSSION

In this paper we have estimated the number of bats of the various species currently living in the state. These estimates are based on assumptions which we cannot adequately assess, particularly those with regard to the big brown bat. Errors in the values for that species of course translate to errors in the other species. However, we are relatively satisfied with our assumptions and our results. We think that they do give a fairly good idea of bat populations in Indiana and that they should provide baseline data for future estimates, either from additional mist-netting or from bats from the rabies laboratory.

The best individual estimates of the total number of individuals of a species are for the Indiana myotis (about 173,000 bats from the 2001 winter counts), and the gray myotis (3700+ from summer emergence [dusk] counts). Thus, these species can be used as a test of the method used below. Our estimate from netting is that Indiana myotis represent about 14.1% of the total capture and when compared to big brown bats, gives an estimate of 156,702. This is relatively close to the number hibernating in caves (173,000) in Indiana, which gives some measure of confidence to these estimates. The difference observed, about 17,000 bats, may be because not all bats that hibernate in Indiana spend the summer in Indiana. Some summer in Michigan (Kurta et al. in press) and we suspect some summer in Ohio and Illinois. The rest probably summer in Ohio, Michigan and Illinois. The gray myotis estimate was 7780 as opposed to about 3700 gray myotis by dusk counts, or about twice the estimate. We did not feel this difference was excessive given the way the estimate was obtained, the small number of gray myotis in the sample, and that only one colony of gray myotis was involved.

ARE BATS DECLINING?

It appears to us that Indiana myotis, gray myotis, big brown bats, and eastern pipistrelles have increased in Indiana, whereas red bats, hoary bats, evening bats, and little brown myotis have declined over the last four decades. It is difficult to determine the status of the northern long-eared bat and the silver-haired bat. The southeastern myotis has been extirpated, and Rafinesque's big-eared bat should be considered of only accidental occurrence in Indiana.

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LITERATURE CITED

Brack, V., Jr. & K. Dunlap. 1999. Winter survey for Indiana bats, *Myotis sodalis*, in hibernacula of Indiana. Final Report, Indiana Department of Natural Resources, Indianapolis. 73 pp.

Butler, A. 1895. The mammals of Indiana. Proceedings of the Indiana Academy of Science 4: 81–86.

Cope, J.B., W.W. Baker & J. Confer. 1961. Breeding colonies of four species of bats of Indiana. Proceedings of the Indiana Academy of Science 70:262–266.

Cope, J.B., J.O. Whitaker, Jr. & S.L. Gummer. 1991. Duration of bat colonies in Indiana. Proceedings of the Indiana Academy of Science 99: 199–201.

Kurta, A., S.W. Murray & D. Miller. In press. Indiana bats: Journeys in space and time. *In* Indiana Bats: Biology and Management of an Endangered Species (A. Kurta & J. Kennedy, eds.). Bat Conservation International, Austin, Texas.

Mumford, R.E. & J.O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press. Bloomington. 537 pp.

Richter, A.R., S.R. Humphrey, J.B. Cope & V. Brack, Jr. 1993. Modified cave entrances – Thermal effect on body mass and resulting decline of endangered Indiana bats, *Myotis sodalis*, in southern Indiana. Conservation Biology 7: 407–415.

Tuttle, M.D. & J. Kennedy. 1999. Indiana bat hibernation roost evaluation. Phase II. Results from the first annual cycle. Bat Conservation International. 11 pp. plus appendices.

Whitaker, J.O., Jr. & S.L. Gummer. 1993. The status of the evening bat, *Nycticeius humeralis*, in Indiana. Proceedings of the Indiana Academy of Science 102:283–291.

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.

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