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STATUS OF CAVE-DWELLING BATS IN MARYLAND: IMPORTANCE OF MARGINAL HABITATS[1]

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Caves, mines, and tunne1s may serve as nurseries, hibernacula, or temporary roosting sites for many North American species of bats. In Maryland, such structures are used as hibernacula and roosting sites by at least 6 species: the little brown bat (*Myotis lucifugus*), Northern bat (*M. septentrionalis*), Indiana bat (*M. sodalis*), eastern small-footed bat (*M. leibii*), eastern pipistrelle (*Pipistrellus subflavus*), and big brown bat (*Eptesicus fuscus*). However, caves are rare, unique, and fragile habitats (Maser *et al.* 1979). Many populations of cave-dwelling bats have been adversely affected locally by pesticide or other chemical pollution, cave c1osures, vandalism, impoundments, or speleological activities (Humphrey 1978, Tutt1e 1979, LaVal and LaVal 1980, Clark 1981). In order to provide baseline management information on the distribution and numbers of cave-dwelling bat species in Maryland, we surveyed most of the caves, mines, and tunnels in the state.

STUDY AREA AND METHODS

Caves surveyed were in the 4 westernmost counties of Maryland. These counties contain 142 of the 148 caves (95.9%) known to occur in the state. Names, locations, and descriptions of caves surveyed are contained in Franz and Slifer (1976).

Garrett County (13 caves) is in the Allegheny Plateau physiographic province. Most of Allegany County (30 caves), Washington County (89 caves), and the western one-third of Frederick County (3 caves) lie in the Ridge and Valley physiographic province. The eastern two-thirds of Frederick Counly (7 caves) are in the Piedmont physiographic province. Topographic descriptions of physiographic provinces are in Paradiso (1969). The forests of the Allegheny province are composed of Canada hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), red maple (*A. rubrum*), American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), black cherry (*Prunus serotina*), and several oaks (*Quercus rubra*, *Q. alba*, *Q. prinus*). The forests of the Ridge and Valley province are dominated by chestnut oak, with scarlet (*Q. coccinea*) and scrub (*Q. ilicifolia*) oaks on the higher ridges and white and black (*Q. velutina*) oaks at slightly lower elevations and on the valley floors (Brown and Brown 1972). In the Piedmont province, forests consist of white oak, black oak, North American tuliptree (*Liriodendron tulipifera*), pignut hickory (*Carya glabra*), and flowering dogwood (*Cornus florida*).

Two techniques were used: visual inspection of sites from late fall through early spring for hibernating bats, and mist-netting during the remainder of the year. Forty-nine sites were censused completely for hibernating bats during 55 trips from 9 October 1979 through 10 April 1980. Forty-five sites were censused during 49 trips from 19 November 1980 through 26 March 1981. Several surveys also included in this paper were done in years prior to or after the major survey effort. Numbers of individual bats of each species observed throughout each site were recorded. Mist-netting surveys were conducted for 111 nights at 17 sites: 41 from 18 July to 5 November 1979; 62 from 10 April to 7 November 1980; and 8 from 19 May to 2 June 1981. A 1.9-cm mesh nylon mist-net was placed at the entrance or slightly inside each site and monitored continuously. We attempted to cover as much of the entrance as possible with netting. Initially, the net was set about 1.5 hours after sunset and left in place from 30

to 226 min (x = 80 ± 3.2 SE, *n* = 111). No surveys were done during rainy weather or periods of high winds. The species and sex of each bat were recorded. Bats were then placed in a holding cage to prevent their recapture that night. All bats were released at the end of the netting period.

Reliability of cave surveys in identifying species occurrence in hibernacula was evaluated using modified bat traps at 1 major hibernaculum to monitor bats leaving the cave after the hibernation period (Tuttle 1974). An inner trap was used to capture bats exiting the cave and an outer trap was used to capture bats entering. Traps usually were set prior to sunset and checked after sunrise. We attempted to monitor the cave 3 times/week during late winter and spring 1982.

RESULTS AND DISCUSSION

Hibernating populations generally were small, but fairly stable, within the sites surveyed in western Maryland (Table 1). Hibernacula containing re1atively large numbers of bats inc1uded Crabtree and John Friend caves in Garrett County, Devils Hole Cave and the Paw Paw C & 0 Canal Tunnel in Allegany County, and the Round Top Mines complex in Washington County. Generally, only 2–3 bat species were found at a location.

Several factors probably influenced the number of bat species found hibernating in any particular site. These inc1uded the dimensions and complexity of the hibernaculum, ambient temperature, and the presence or absence of water (Tuttle and Stevenson 1978, LaVal and LaVal 1980). Certain species were generally associated with particular types of hibernacula. Big brown bats were found primarily in mines and tunnels (282 of 333); little brown bats were more abundant in the larger, more complex caves (181 of 202); and eastern pipistrelles were common over a wide range of hibernacula.

The seasonal capture rates of individual bat species by mist-netting were similar among years. Therefore, we combined the data (Table 2). Caves, mines, and tunnels with large numbers of hibernating bats also were used most often during the pre- and post-hibernation period. Bat species using these sites outside the hibernation period also tended to use them for hibernation. The exception to this observation was the northern bat. Large numbers of this species were netted at the entrance to Crabtree and John Friend caves in Garrett County, and Devils Hole and Greises caves in Allegany County. This species is rare in the Appalachian Mountains (Barbour and Davis 1969), and we found few individuals hibernating in these caves during winter surveys (Table 1). We believe the northern bat is either migratory in western Maryland or always hibernates in inaccessible locations in caves.

Barbour and Davis (1969:76) stated that the summer and winter ranges of this species appear to be the same. Bat traps at Crabtree Cave captured large numbers of emerging northern bats of both sexes from 18 March through 8 June 1982 (Fig. 1). Thus, northern bats appear to hibernate in western Maryland. In eastern Missouri, Caire *et a1*. (1979) noted that hibernating northern bats commonly are secluded in the formations of the cave, resulting in few actually being seen. Emerging individuals often were covered with mud and clay, suggesting they had been roosting in crevices.

Most bats captured by mist-netting were males (Table 2). During June and July, this bias is expected because females are in nursery colonies. As females and young leave maternity roosts later in the summer, the sex ratios of mist-netted bats at cave entrances should approach 1:1. However, as in our study, the preponderance of males among fall-swarming little brown bats has been noted previously (Davis and Hitchcock 1965, Humphrey and Cope 1976, Schowalter 1980). Males of some species often remain active later in autumn than females, staying outside the caves to breed (Tuttle 1976, Humphrey and Cope 1977). Also, females may have been segregated spatially or temporally during foraging activity.

Seasonal capture rates were variable (Table 2). The number of captures per hour generally increased from late spring into late summer and early fall and then decreased as some bats entered hibernation. Elevated capture rates toward the end of the summer and in early fall probably were related to bats congregating at temporary or winter roost sites prior to hibernation; that is, autumnal “swarming” activity (Humphrey 1982:58). Similar trends in capture rates have been reported (Humphrey and Cope 1976, Cope and Humphrey 1977) and probably vary temporally with differences in latitude and elevation of study sites as well as with bat species.

MANAGEMENT CONSIDERATIONS

Based on our surveys, hibernacula in Maryland appeared somewhat marginal. None contained more than 100 individuals, and only 4 hibernacula had 50 or more individuals. However, these values probably

Table 1. Maximum number of bats found hibernating in important hibernacula (10 individuals) in Maryland during winter surveys. Except where indicated, all surveys of hibernacula were completed between 15 November and 20 March with 81.2% of them conducted from December through February.

		Species						
Garrett County	No. of	*Myotis*	*Myotis*	*Myotis*	*Pipistrellus*	*Eptesicus*		
Crabtree Cave	surveys	*lucifugus*	*septentrionalis*	*leibii*	*subflavus*	*fuscus*	Unknown	Totals
1979–1980	1	20	—	—	13	—	25	58
1980–1981	1	48	—	—	20	—	3	71
1981–1982	1	35	1	—	33	1	5	75
Crabtree Mine								
1979–1980	1	1	—	—	—	5	—	6
1980–1981	1	—	—	—	—	6	—	6
1981–1982	1	—	1	—	—	9	—	10
John Friend Cave								
1977–1978	1	19	—	—	38	—	—	57
1978–1979	2	26	—	—	31	1	—	58
1979–1980[a]	2	5	1	—	18	—	6	30
1980-1981	1	24	—	—	29	—	—	53
Other hibernacula								
1979–1980 (*n* = 1)	1	—	—	—	—	—	—	—
1980–1981 (*n* = 1)	1	—	—	—	—	—	—	—
Allegany County								
Devils Den								
1979–1980	1	10	—	1	4	1	—	16
1980–1981	1	—	—	—	7	—	—	7
Devils Hole Cave								
1979–1980[b]	2	2	—	—	28	—	1	31
1980–1981[c]	2	1	—	—	43	—	6	50
Greises Cave								
1979–1980	2	—	1	—	12	—	—	13
1980–1981	2	1	—	—	10	—	—	11
Horse Cave								
1979–1980	1	—	—	—	20	—	—	20
1980–1981	1	—	—	—	13	—	—	13
Paw Paw C & O Canal Tunnel								
1980–1981	1	—	—	—	—	91	2	93
1981–1982	1	—	—	—	—	75	4	79
Pinto Limestone Cave								
1979–1980[d]	3	—	—	—	10	2	2	14
1980–1981	1	—	—	—	19	—	—	19
Pinto Limestone Mine No.1								
1979–1980	2	—	—	—	—	12	1	13
1980–1981	2	—	—	—	—	2	1	3
Other hibernacula								
1979–1980 (*n* = 11)	1	—	—	—	7	—	1	8
1980–1981 (*n* = 6)	1	—	—	—	6	5	1	12
Washington County								
Dam No.6 Mine								
1979–1980	1	—	—	—	5	—	—	5
1980–1981	1	—	—	—	12	1	—	13
Round Top Mine No.2								
1977–1978	1	—	—	—	2	8	—	10
1979–1980	1	2	—	—	—	5	—	7
1980–1981	1	—	—	—	—	8	—	8
Round Top Mine No.7								
1977–1978	1	—	—	—	1	1	—	2
1979–1980	1	1	—	—	6	—	—	7
1980–1981	1	3	—	—	7	3	—	13
Round Top Summit Cave								
1979–1980	1	1	—	—	11	—	1	13
1980–1981	1	—	—	—	21	—	2	23
Other hibernacula								
1978–1979 (*n* = 4)	1	—	—	—	4	16	—	20
1979–1980 (*n* = 21)	1	3	—	—	25	9	1	38
1980–1981 (*n* = 22)	1	—	—	—	25	32	—	57
Frederick County								
Other hibernacula								
1979–1980 (*n* = 2)[e]	1	—	—	—	1	—	—	1
1980–1981 (*n* = 1)	1	—	—	—	1	—	—	1

[a] *Includes a survey from 9 October 1979.*
[b] *Includes a survey from 25 October 1979.*
[c] *Includes a survey from 26 March 1981.*
[d] *Includes a survey from 10 April 1980.*
[e] *Includes a survey from 31 March 1980.*

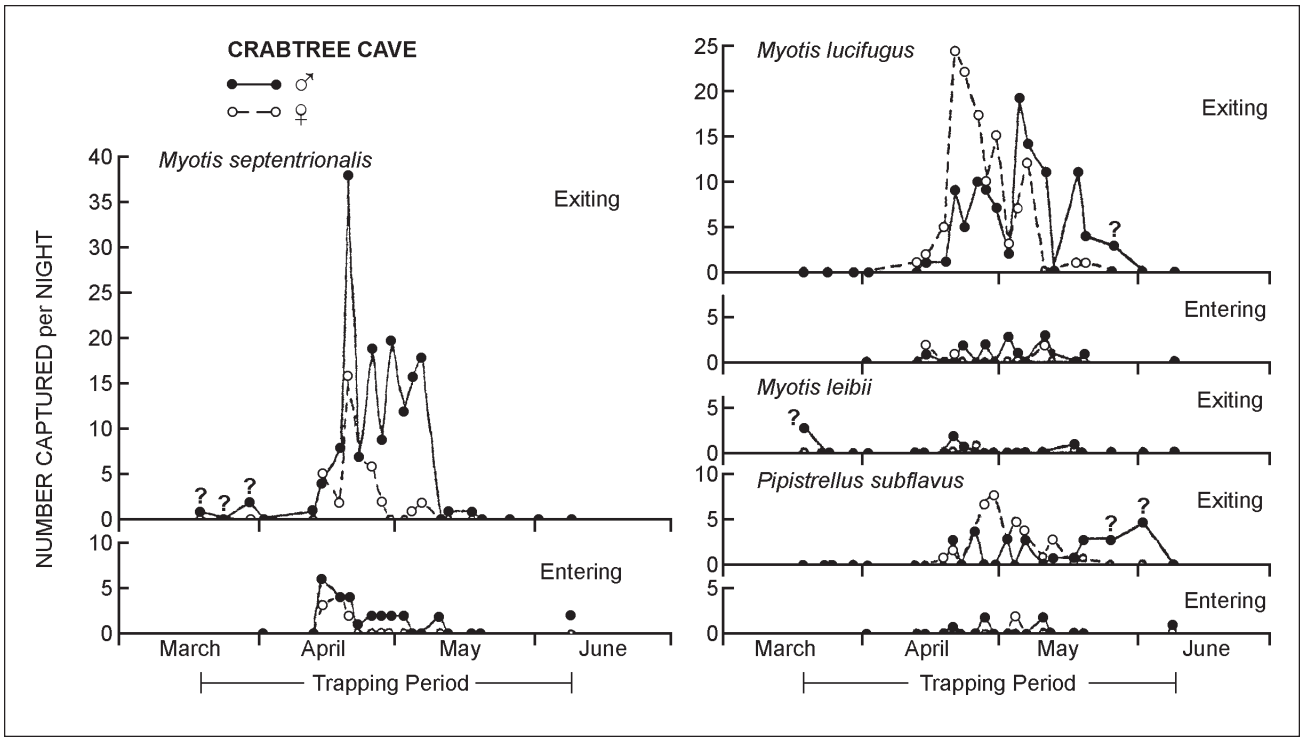

Figure 1. Emergence of cave-dwelling bats in late winter and spring from Crabtree Cave, Garrett County, Maryland. Captures resulting from use of only the inner bat trap (denoted by?) may be the result of bats entering as well as exiting the cave.

represent minimum numbers of bats actually inhabiting these sites, as several species besides the northern bat seek secluded crevices in which to hibernate. This behavior points to the need of conducting both cave surveys, and mist-netting or live-trapping surveys to properly assess populations.

Continued loss of the most important hibernacula in the state could adversely affect hibernating populations of bats. Devils Hole Cave currently is threatened by the construction of a highway. During the spring of 1981, the entrance to John Friend Cave was filled with large rocks, effectively closing the only known entrance. Because of the philopatry exhibited by many bat species (Humphrey and Cope 1976, Tuttle 1976, Caire *et a1*. 1979, Humphrey 1982), we assume that many of the bats that hibernated in John Friend Cave may have died. This amounts to 19–27% of the little brown bats and 15% of the eastern pipistrelles known to hibernate in Maryland. Even if this cave is reopened, these bat species may not reoccupy the site (Rabinowitz and Tuttle 1980).

John Friend Cave was also 1 of only 2 caves in which we found the endangered (U. S. Fish and Wildlife Service 1978) Indiana bat, the other being Round Top Mine No. 4 in Washington County. The previous records of the Indiana bat in Maryland are also from these locations: a male from John Friend Cave taken 17 October 1941 (National Museum of Natural History [NMNH] No. 270421, skull only); a male banded at Round Top Mines on 9 December 1950; and a male collected in Round Top Mines on 15 November 1978 (NMNH No. 529697). Historically, neither site probably contained large populations of Indiana bats. .

Stronger efforts to diminish or alleviate disturbance, such as those discussed by Harvey (1975), Tuttle (1979), Rabinowitz and Tuttle (1980), and Humphrey (1982), must be instituted if bat populations are to survive in Maryland and elsewhere. As indicated by our surveys, only a few of the known caves in Maryland are suitable hibernacula for bats. Tuttle and Stevenson (1978) noted that cave-dwelling bats are often severely roost-limited. Caves with comparatively large populations (approximately 30 individuals or more) must be acquired or protected by state or private conservation agencies. However, because many privately owned caves are small and have small numbers of bats using them, justifying preservation is often difficult. Why should we be concerned with such apparently marginal bat habitat?

Hibernacula can be viewed as islands of different sizes and complexities in an ocean of habitat

Table 2. Mean number of bats captured per hour during 2-month periods in important caves and mines western Maryland counties from 1979 to 1981. Number of hibernacula is in parentheses.

	Species[a]							
	Myotis lucifugus		*Myotis septentrionalis*		*Pipistrellus subflavus*		*Eptesicus fuscus*	
	♂	♀	♂	♀	♂	♀	♂	♀
Garrett County (*n* = 3)								
May–Jun (7.5 hours)[b]	0.53	0.13	0.53	0	0.67	0	0.13	0
Jul–Aug (22.7 hours)	2.29	0.53	5.64	0.97	2.11	0.09	0	0
Sep–Oct (10.7 hours)	3.93	1.59	2.43	0.66	0.37	0.37	0	0
Allegany County (*n* = 6)								
May–Jun (16.6 hours)	0.30	0	0.42	0	0.24	0	1.45	0
Jul–Aug (33.6 hours)	0.36	0.06	1.46	0.24	1.01	0.12	1.52	
Sep–Oct (19.8 hours)	0.91	0.05	1.51	0.50	0.76	0.15	0.05	0
Washington County (*n* = 8)								
May–Jun (5.3 hours)	0.19	0.19	0	0	0.75	0.19	4.88	0.10
Jul–Aug (12.5 hours)	0.72	0.08	0	0	1.12	0.16	9.51	1.70
Sep–Oct (14.1 hours)	0.36	0.14	0	0	0.36	0.28	0.43	0.20

[a] *Myotis sodalis* was taken at 1 site in Garrett County (*n* = 2 individuals) and at 1 site in Washington County (*n* = 1) in August 1979. *Myotis lucifugus* was taken at 1 site in Garrett County in August 1979 (*n* = 1); at 1 site in Allegany County in July (*n* = 1) and August (*n* = 4) 1980 and September (*n* = 1); and at 1 site in Washington County in September 1979 (*n* = 1).
[b] Total hours spent mist-netting at sites within each 2-month period.

inhospitable for hibernation. Loss of hibernacula contributes to habitat insularization, i.e., increased distances between suitable hibernacula. Although bats can and do disperse widely, hibernaculum loss might delay or limit occupation of suitable summer habitat and could result in contracted geographical ranges, especially near the periphery of a species distribution (Tuttle and Stevenson 1978). Long distance migration is energetically costly (Tuttle 1976), and may increase mortality rates (Tuttle and Stevenson 1977). Furthermore, by reducing accessibility and source of colonists, extinction events may be less easily offset (Wilcox 1980). If a species has its population confined to 1 or 2 major hibernacula and several minor ones, the minor ones could serve as possible sources of colonists to the major hibernacula if those populations decline dramatically due to disturbance or natural disasters. Further, minor hibernacula may become major ones (depending on their size, configuration, and microclimate) if the latter are destroyed, and may function to promote further range expansions. Based on our observations, disturbance from spelunkers could be the most important factor limiting size of bat populations in several Maryland caves. These small populations become increasingly important in species management when larger populations are continually threatened (Humphrey 1978). Careful monitoring of bat populations in small hibernacula might indicate whether a regional population is increasing or decreasing. Marginal hibernacula may also maintain or foster genetic diversity (see Soulé and Wilcox 1980), an important function in the adaptability of bat species to environmental change.

SUMMARY

The use of different caves, mines, and tunnels by cave-dwelling bat species in western Maryland was assessed primarily during 1979–1981. Population density estimates were low but stable at most sites. Use of a site for winter hibernation by a bat species appeared to be related to its use by that species at other times of the year. The importance of marginal hibernacula to several species of bats is discussed relative to increased habitat loss and insularization.

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