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SEASONAL ACTIVITY PATTERNS IN THE BAT COMMUNITY AT NEDA MINE

Even though bats represent a relatively abundant, biologically fascinating and highly beneficial component of Wisconsin's wildlife, they remain poorly studied and greatly misunderstood. The acquisition of the Neda Iron Mine property, currently maintained by the UWM Field Station, provided an opportunity to narrow the gap in our knowledge of the ecology and behavior of this mammalian order. This abandoned mine, located approximately 80 km northwest of Milwaukee, is the largest known bat hibernation site, or hibernaculum, in the state.

Hibernation is considered one major solution to periodic resource depletion. A thermally suitable hibernaculum and the seasonal activity patterns associated with it are crucial to bat survival especially in a climatic region characterized by a winter of 5 to 7 months duration. The significance of Neda Mine is readily apparent with the realization that all Wisconsin bats are nocturnal, aerial insectivores.

Accounts of the seasonal adaptive strategies of most bats are inadequate or fragmentary (Barbour and Davis 1969). Rarely have researchers investigated more than one species at a single time and place. The aim of this study was to make simultaneous comparisons by sex and species of the various adaptive strategies employed by members of the Neda Mine bat community on an annual basis. Specifically, it was asked: How do bat annual activity cycles differ, and what potential survival advantages are gained by varying annual cycles between sexes or among species?

METHODS

Bat activity was monitored from August 1978 through November 1979 via modified harp traps (Tuttle 1974) and nylon mist nets set at mine entrances from sundown till midnight. Observations were continued all night at least once in each season except winter. Trapping and netting were limited to two entrances. Traps were consistently set at one entrance leading into the coldest area of the mine (site I) while nets were placed at an opening that led directly into one of the warmest areas (site II). Sampling occurred at daily to 9-day intervals in spring and fall, at 7 to 14-day intervals in summer and once per month in December, January and February. Bats were removed from traps at hourly intervals except during periods of peak activity when they were removed every 10 minutes. Nets were similarly checked at 10 to 30 minute intervals. All captured bats were placed in nylon bait bags and hung on trap sides or net poles till midnight. At that time bats were recorded by time of capture, species and sex.

In conjunction with entrance trapping, surface air temperatures were measured using a Wesco maximum/minimum mercury thermometer. To gain insight into the local availability of potential prey, relative insect abundance was also sampled simultaneously along a north-south 60 m. transect near trap site I. A total of four plastic cylinders were coated with a sticky substance, Tanglefoot, and placed at ground level and heights of 1, 2 and 3 m., spaced at 15 m. intervals. Insects were counted, identified by order, and body length was measured to the nearest 1.0 mm. These data were converted into insect biomass units employing the technique of Bradbury and Vehrencamp (1976).

To check entrance trapping results, daytime surveys were made in the mine during all seasons. A pre-determined route, covering approximately one-fifth of the mine, was followed on each visit. Other areas were not sampled to minimize disturbance to the bats. Torpid individuals were collected periodically along the route, and numbers, species and sex were recorded.

RESULTS AND DISCUSSION

In this study 5,568 *Myotis lucifugus* (the little brown bat), 111 *Myotis keenii* (the long-eared bat), 37 *Pipistrellus subflavus* (the eastern pipistrelle), and 35 *Eptesicus fuscus* (the big brown bat), were trapped or netted on a total of 62 nights. These proportions were in close agreement with estimates from inside the mine and probably provide the most reliable assessment of relative species abundance at Neda.

Individuals of *M. lucifugus* trapped at site I were used in total capture rate calculations (bats/hour for any given date), reflecting overall bat activity on an annual basis (Figure 1). When trapping began in late August, large numbers of bats of both sexes were present. The majority were caught beginning 1 hour after sunset, entering as well as exiting the mine. This flow of bats continued at a nearly steady rate until almost dawn. Daytime surveys, however, revealed few torpid individuals inside the mine. Apparently, sizeable bat aggregations make late summer visits to Neda, not for premature hibernation, but remain only for short periods of time before dispersing. The functions of this phenomenon, known as swarming, have been postulated by Fenton (1969) to include: the beginning of acclimatization processes and initial site selections for hibernation, familiarization of the young with a potential hibernaculum, mixing of sexes from different parts of the species range in the onset of mating, and/or a temporary retreat for some early migrants.

By mid-September, swarming behavior at Neda mine had ceased. In contrast to the previous period, bats began to exit the mine during the first hour following sunset and, with the exception of a single female, this sample was composed exclusively of males. The time of the maximum entry of bats of both sexes was two to three hours after sunset, with activity declining by midnight. As the season progressed, the first-hour fraction of males constituted an increasingly greater proportion of the total nightly catches. These exiting males characteristically exhibited fur streaked with reddish-orange soil and clay particles embedded around their claws, indicating recent roosting contact with the muddy interior of the mine.

During the fall arrival period at Neda, it appears that female *M. lucifugus* enter hibernation and probably do not emerge until spring while males emerge nightly at dusk to feed. Fall hibernation coincides with the mating period in *M. lucifugus,* as confirmed by observations of copulation and the presence of sperm smeared on the fur of captured females. Since breeding in little brown bats has been described as promiscuous (Thomas *et al* 1979), males would be expected to find and inseminate as many females as possible. By feeding between breeding and entry into hibernation, males can replenish lost fat; females appear to have little need to forage, not having expended large amounts of energy in multiple mate searches and copulations. Furthermore, their inactivity may be advantageous to successful sperm storage after breeding (Wimsatt 1944).

No bats were trapped from late November until mid-April. This period represented the time of deep hibernation within the mine. No insects were captured during these months and the surrounding area usually remained covered by snow. It is possible that in more mild southern latitudes or during mid-winter thaws, bats periodically emerge to feed. However, there was no evidence of mid-winter foraging at Neda.

In spring, both male and female captures were low and nearly equal at first, but over 75% of total female emergence had occurred by early May. Most of these females were trapped while exiting the mine during the first two hours following sunset. Emergence of males peaked two to three weeks later than females. The differential departure of the sexes following hibernation is documented for a number of bat species (Daan 1973; Humphrey and Cope 1976; Tuttle 1976). It may be highly benficial for females to depart as soon as possible, since fertilization is delayed until spring dispersal. Males, on the other hand, have spent their reproductive energy mainly in the pre-hibernation copulations. Having no immediate energy demands, individuals may remain within the shelter of the mine until some minimum weight is reached and emergence becomes absolutely necessary. In fact, early male departure may be disadvantageous by creating potentially competitive situations with pregnant females that have elevated energy needs.

Although small numbers of males used the mine as a day roost in early summer, gradually increasing their use as the season progressed, no females were captured until the end of July, when swarming again commenced. Temperature ranges in the mine may be ideal for hibernation, but are far too low to permit rapid growth and development of young (Racey 1969; Tuttle 1975). Also, the increased metabolic needs of females stemming from gestation, parturition, and lactation are partially offset by roosting away from the mine at moderately high temperatures in barns, attics, etc. where thermoregulation costs are reduced and digestion proceeds more efficiently (Stones 1965).

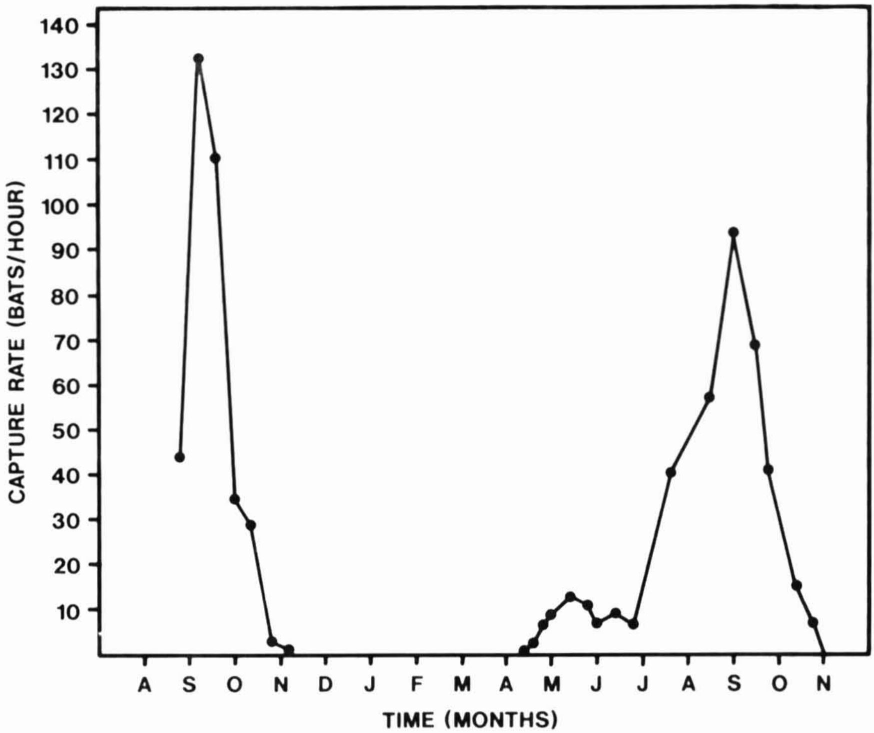

Figure 1. Annual activity cycle of *Myotis lucifugus* trapped at the Neda Iron Mine, site I.

Generally this model of late summer swarming, fall arrival, mating, and entrance into torpidity, deep winter hibernation, and spring dispersal to summer ranges can be utilized in the understanding of the seasonal activity cycles of the four bat species at Neda mine. However, individual species patterns are temporaily distinct. *P. subflavus* and *E. fuscus* exhibited the two most extreme examples. *P. subflavus,* the smallest bodied bat in the state, entered hibernation early in the fall, before resource depletion or first autumnal frost (October 8). They remained torpid for some 230-245 days until after the last vernal frost (May 5), thereby limiting the possibility of freezing to death or of facing periods of low food availability. This strategy entails being a "prudent hibernator."

The strategy of *E. fuscus,* the largest-bodies hibernator, is in sharp contrast. Big brown bats remained active well after other bats had entered hibernation, and potentially competitive avian counterparts had migrated southward, thus permitting exclusive exploitation of local food patches on exceptionally warm autumn nights. *E. fuscus* began arrival at the mine only after freezing temperatures in late fall. They employed an "early bird" strategy, departing in late March and early April, a hibernation interval of 150-170 days. Such timing alleviates overt interspecific competition since other bats were still hibernating, and most nocturnal insectivorous birds had not yet begun their northward migration to the state. *Eptesicus* apparently enter torpor in roosts outside the mine, are capable of surviving even sub-freezing temperatures and are able to exploit early spring insect biomass during warming trends. Thus, these exceptionally hardy bats can profit from an otherwise largely unharvested food supply, in the face of seemingly harsh conditions.

Adaptive strategies of the two *Myotis* species fall between the previously discussed extremes. Most *M. lucifugus* entered hibernation between late September and early October, before the first autumnal frost, emerging in mid-May after the last vernal frost, approximately 215-230 days, similar to *Pipistrellus*. In contrast, the majority of *M. keenii* entered hibernation after the first autumnal frost and emerged in late April, before the last freeze in spring, displaying a more *Eptesicus*-like behavior, with an interval of some 190-210 days.

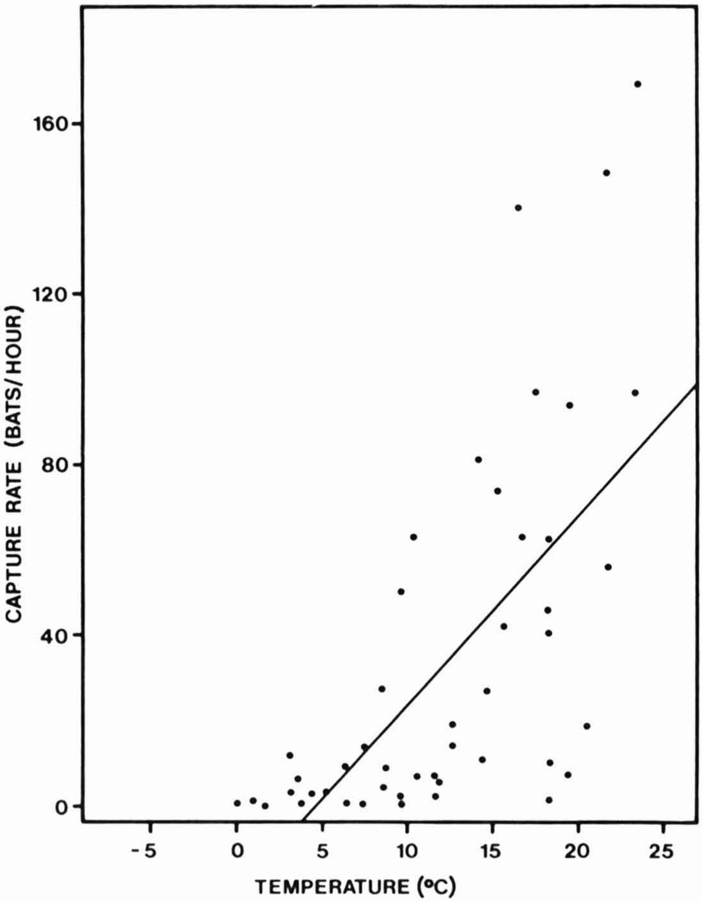

Figure 2. Relationship between ambient temperature (mean for each trapping period) and activity of *Myotis lucifugus* at the Neda Iron Mine, site I.

While the overall gross calendar timing of each species' entrance into hibernation may be determined ultimately by genetic differences in the degree of physiological interplay with such environmental factors as changing photoperiod, their activity on any given night may be cued proximately to ambient climatic conditions, as seen especially with *M. lucifugus*. Trap captures were low during precipitation, fog, high wind and/or low temperatures. In illustration, the overall number of bats captured per hour at site I for all dates combined was plotted against mean temperature recorded on that night (Fig. 2), and a regression line was calculated for the points ($Y=20.26 + 4.43x$). A one-way analysis of variance indicated a highly significant relationship ($F=32.0$. $P<0.0005$) between bat activity and temperature, despite the fact that very few bats were present on warm early summer evenings, and that bat activity peaks were in spring and fall, when temperatures were generally low. As seasonal samples of relative insect biomass from this study suggest, bat activity may be indirectly correlated with the behavior of prey. It is understandable that *M. lucifugus* would largely restrict its activity, both in fall and spring, to relatively warm periods, when prey items would be encountered more frequently.

From the preceeding discussion it is clear that members of the Neda mine bat community employ a variety of strategies in dealing with the vagaries imposed by a north temperate climate. Moreover, intraspecific modes differed as well. Development of species–distinctive temporal patterns of seasonal activity, through a complex of physiological and behavioral adaptations, is one major means of successfully partitioning a shared hibernaculum and enhancing the probability of survival over relatively long stressful periods of food shortage and cold.

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