

# No lunar phobia in swarming insectivorous bats (family Vespertilionidae)

Britt-Louise Karlsson, Johan Eklöf and Jens Rydell\*

Zoology Department, Göteborg University, Box 463, SE-405 30 Göteborg, Sweden

(Accepted 22 March 2001)

## Abstract

The purpose of this study was to evaluate the impact of moonlight on the swarming activity of bats at an abandoned mine in southern Sweden. The mine serves as a hibernaculum for six species of insectivorous bats. Swarming activity at one of the mine entrances was measured on 12 nights between 1 August and 8 September 2000, by electronically counting the number of bats passing through an opening (about 30 × 40 cm) leading to a mine tunnel. The number of bat passes outside the mine was also counted, using a bat detector. Most bats were males, as confirmed by mist-netting outside the mine. Low frequency vocalizations, indicating territorial interactions, were heard frequently. The number of bats entering the mine was closely correlated with the number of bats flying outside, and neither was affected by moonlight. We conclude that the insectivorous bats at high latitudes may not have been exposed to significant nocturnal predator pressure, leading to the evolution of lunar phobia, as have many tropical bats.

**Key words:** moonlight, insectivorous bats, owls, predation, swarming activity, vision

## INTRODUCTION

Several species of nocturnal mammals and birds alter their activity patterns during moonlit nights. For example, the Galapagos fur seal *Arctocephalus galapagoensis* dives less often but deeper on moonlit nights (Horning & Trillmich, 1999). Australian owl nightjars *Aegotheles cristatus* reduce their foraging activity to a minimum during full moon nights (Brigham *et al.*, 1999). Two studies conclude that high latitude (above 40°) insectivorous bats may change foraging habitats as a result of moonlight (Reith, 1982; Hecker & Brigham, 1999) although other studies indicate that bat activity at high latitudes is not influenced by moonlight (Wai-Ping & Fenton, 1989; Rydell, 1991; Negraeff & Brigham, 1995). In contrast, in the tropics, the short-tailed fruit bat *Carollia perspicillata*, which has been studied intensively, reduces foraging activity considerably during bright moonlight, more so in the dry season than in the wet season (Fleming, 1988). Such 'lunar phobia' is apparently widespread in tropical frugivorous bats (Morrison, 1978; Usman *et al.*, 1980) and has also been observed in vampire bats *Desmodus rotundus* (Turner, 1975). Frugivores and sanguivores are perhaps most at risk when they approach their food sources.

It has been hypothesized that bats avoid flying in

moonlight due to the increased risk of predation by nocturnal but visually orienting birds such as owls and bat hawks *Machaeramphus alcinus*. Owls are known to prey on bats at least opportunistically (Krzanowski, 1973; Ruprecht, 1979; Speakman, 1991a), and bat hawks are specialized predators on bats (Hartly & Hustler, 1993). Insectivorous bats are probably most vulnerable when leaving the day roost and perhaps also when they return. This is partly because the simultaneous appearance of many bats at a predictable site favours opportunistic predators and partly because there is often still enough light at dusk to permit visually hunting diurnal predators to be active (Fenton *et al.*, 1994; Jones & Rydell, 1994; Kalcounis & Brigham, 1994; Speakman, Stone & Kerslake, 1995).

The purpose of our study was to assess whether insectivorous bats exhibit lunar phobia at high latitudes (in this case 57° N) during the swarming period in late summer. This is the time of year when many bats concentrate activity at predictable sites for an extended period (Fenton, 1969; Thomas, Fenton & Barclay, 1979; Wai-Ping & Fenton, 1988; Whitaker & Rissler, 1992; Degn, Andersen & Baagøe, 1995) and hence when they may be expected to be particularly susceptible to predators (Fenton *et al.*, 1994). We monitored a community of bats consisting of six different species using a mine in southern Sweden. During the study period the majority of bats entering the mine tunnel were males (Rydell, Gerell & Apelkvist, 1999). The mine

\*All correspondence to: Jens Rydell  
E-mail: jens.rydell@zool.gu.se

is used as a hibernaculum by bats in winter, but bats are also active in and around the mine during the summer (Rydell *et al.*, 1999).

## MATERIALS AND METHODS

### Study area

Taberg is an abandoned iron ore (magnetite) mine situated in the middle of a village with the same name, located approximately 13 km south of Jönköping in southern Sweden (57° N). Taberg consists of an isolated hill that was mined from the Middle Ages until the 1950s, mostly using open pits. It also includes *c.* 2.5 km of mine tunnels and shafts in 2 separate systems with 2 major entrances to each system (Rydell *et al.*, 1999). The tunnels have been closed to human visitors in winter since 1986, except for an annual bat census.

### Bat counts

On 12 nights between 1 August and 8 September 2000 we monitored the activity of the bats at 1 entrance to the mine and *c.* 10 m away from the mine entrance, above a trail running alongside the hill between the different entrances. We measured bat activity in 2 ways. Firstly, we counted the number of bats entering the mine through a small (30 × 40 cm) opening in 1 of the gates, using an infra-red photocell connected to a custom-made electronic counter. The opening was located *c.* 2.5 m above the ground and the photocell was placed so that no bats could pass through the entrance unrecorded. Secondly, we counted the number of bat passes over the trail manually, using a Pettersson bat detector D-920 set at *c.* 40 kHz.

Counts were made between 22:00 and 01:00, except for the first 2 nights (1 and 2 August), when we stopped at 24:00. On 1 August the time of sunset was 21:20. Hence the bat counts started 40 min after sunset at the earliest, which excluded the twilight period (the first hour or so after sunset is when the bats normally feed and when few if any enter the mine). In August the time between 22:00 and 01:00 is dark even at 57° N, and this period normally encompasses most in-flights into the mine, but very few out-flights, which predominate after midnight (Rydell *et al.*, 1999). We therefore assume that the number of bats passing the switch represents the approximate number of bats entering the mine tunnel that night. However, we did not account for the possibility that the same bat occasionally could have passed the switch more than once.

Dew and water drops occasionally triggered or blocked the switch. To minimize this problem the switch was checked and the counter read and reset manually every 15 min, an operation which took only a few seconds. The light source used to check the switch and the counter was a small (Maglite) torch. To minimize the disturbance, we kept away from the mine entrance

between the readings and avoided using lights as much as possible.

The mine entrance faced east, and was thus illuminated by the rising moon. Moonlight was not measured, but recorded as 'no moon', 'half moon' or 'full moon'. We also recorded if the moon was below or above the surrounding hills and, in the latter case, if it was fully visible or entirely or partly covered by clouds. We measured the air temperature every 30 min, using a digital thermometer, 1 m above the ground and 10 m from the mine entrance. Cloud cover (%), rain, mist and wind speed (calm, light breeze, strong breeze, and strong wind) were also recorded. These parameters remained almost constant throughout the study (clear or almost clear sky, no rain, no strong wind), so they were not included in the analysis.

### Bat species present

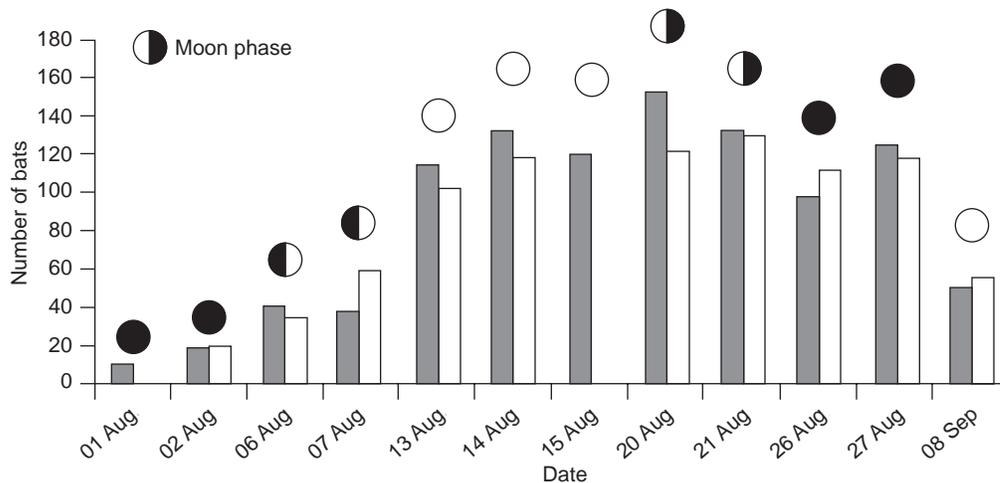
On 8 September we erected a mist net to capture bats for identification at an entrance 20 m from the entrance at which we counted bats. This complemented earlier data on captures of bats outside the mine and counts of hibernating bats inside (Rydell *et al.*, 1999). Based on the most recent (winter 1999–2000) count of hibernating bats, the community at Taberg consists of at least 250 individuals, belonging to 6 species: brown long-eared bat *Plecotus auritus* (48% of the individuals), northern bat *Eptesicus nilssonii* (13%), Daubenton's bat *Myotis daubentonii* (20%), Brandt's and whiskered bats *M. brandtii* and *M. mystacinus* (together 17%) and Natterer's bat *M. nattereri* (2%). The swarming population reflects the hibernating population with regard to species composition, but consists mostly of males (Rydell *et al.*, 1999). For our counts we did not distinguish between species but treated them as 1 population of individuals. All species at Taberg use echolocation calls that include frequencies around 40 kHz, and were therefore detectable through the bat detector.

## RESULTS

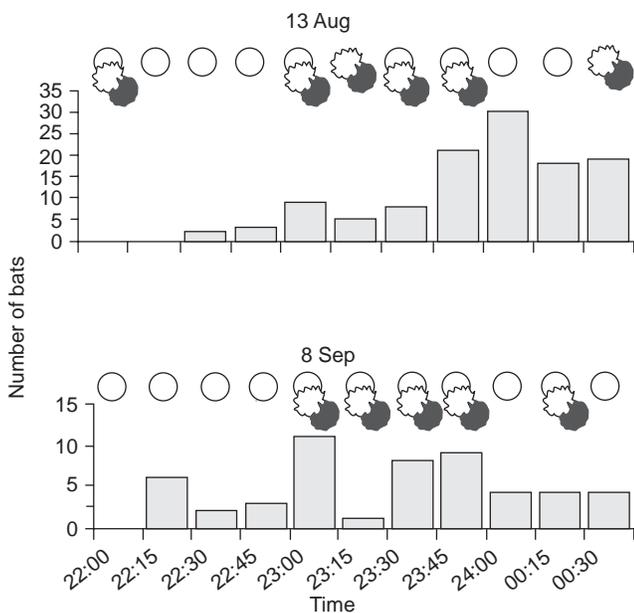
### General observations

Typically bats did not fly straight into the mine tunnel but first circled several times outside the gate. They usually entered the mine in small groups, and there were long periods without any bats passing. Low frequency 'social' calls, easily detectable by the unaided ear, were heard several times each night, usually in association with echolocation calls picked up by the bat detector.

The difference in light intensity between 'moon' and 'no moon' at the mine entrance was obvious to the human eye. During periods with moonlight the bats could easily be seen as they passed over the trail and as they circled outside the mine entrance, while this was not the case when the moon was below the horizon or when it was (occasionally) covered by clouds. Bats



**Fig. 1.** The moon phase and the total number of bats entering a mine tunnel at Taberg each night (grey bars) and the total number of bats passing along a track outside the mine during eight 5-min periods each day (white bars) during the swarming period (1 August to 8 September 2000). The former was measured automatically, using a photoelectric switch, and the latter manually, using a bat detector. Activity was monitored 22:00 to 24:00. Data on bat passes outside the mine are missing for 1 and 15 August.



**Fig. 2.** Bat activity at the mine entrance during each 15-min period of two evenings (13 August and 8 September) when the moon was up in the east but covered by clouds part of the time.

captured were all ( $n=11$ ) young (<1-year-old) males, belonging to four species: *P. auritus* (8), *M. brandtii* (1), *M. daubentonii* (1) and *M. nattereri* (1). We frequently heard *E. nilssonii* with the bat detector. *Myotis mystacinus* was not captured and could not be positively identified based on the echolocation calls.

On three occasions tawny owls *Strix aluco* were heard at the observation point, but this did not have any obvious effect on bat activity. Other raptors and owls,

which also occur at or near Taberg, are sparrow hawk *Accipiter nisus*, goshawk *Accipiter gentilis*, eagle owl *Bubo bubo*, pygmy owl *Glaucidium passerinum*, common buzzard *Buteo buteo* and kestrel *Falco tinnunculus* (B. Lind, pers. comm.).

#### Bat swarming activity

Swarming activity at the mine started in early August and continued until early September, i.e. it occurred during a little more than one lunar cycle. The peak in swarming activity occurred between 13 and 27 August (Fig. 1). The number of bats flying into the mine was highly correlated with the number of passes measured outside the mine ( $r=0.97$ , d.f. = 8,  $P < 0.001$ ), suggesting that swarming activity reflects general bat activity at the mine. Both measures of activity were normally distributed over the period of study and this pattern completely overshadowed any moonlight effect (Fig. 1). There was no indication of bimodality in the data, as would have been expected if moonlight affected the swarming activity.

On two nights (13 August and 8 September) the moon was up, but covered by clouds part of the time (Fig. 2). When the data from these nights were split into 15-min periods, we still could not detect any change in bat activity related to moonlight.

#### DISCUSSION

Our results indicate that the bats do not change their swarming activity at the mine on moonlit nights in any obvious way. Our result is in general agreement with other observations of insectivorous bats (*Euderma maculatum*, *Eptesicus nilssonii* and *Myotis* spp.) in tem-

perate regions (Wai-Ping & Fenton, 1989; Rydell, 1991; Negraeff & Brigham, 1995), although at least two studies suggest that *Myotis* spp. may alter their use of foraging habitats slightly so as to avoid lit areas (Reith, 1982; Hecker & Brigham, 1999). However, the study of Reith (1982) was of very short duration and not conclusive. In the study made by Hecker & Brigham (1999) the observed change in habitat use was subtle and could well have been a response to changed behaviour of their insect prey rather than to increased predation risk for the bats themselves. Hence, there is no undisputed example of insectivorous bats in temperate areas exhibiting lunar phobia. To the best of our knowledge clear cases of lunar phobia in bats are restricted to tropical frugivores and sanguivores (e.g. Turner, 1975; Morrison, 1978; Usman *et al.*, 1980; Fleming, 1988).

It is known that owls, including tawny owls *Strix aluco*, which are common at our study site (B. Lind pers. comm. and J. Rydell, pers. observ.), are capable of catching bats. These events may be opportunistic and bats probably do not comprise a major part of the owls' diet (Krzanowski, 1973; Ruprecht, 1979; Speakman, 1991a). When circling in front of the mine opening, bats were most likely exposed to predators. They were easily visible to us, and therefore presumably also to other animals. Moreover the bats circling near the mine opening must be a predictable and potentially profitable food source for predators. The mine is used by many bats each night for more than a month each year and has been so continuously for many years.

We were surprised to find that the bats did not hesitate to pass through the small opening into the mine, and to circle outside, even when the moon was bright. The bat community at Taberg consists of several species, but is dominated by the brown long-eared bat *Plecotus auritus*, which comprises about half the population. This species flies slowly (Norberg & Rayner, 1987) and emerges to feed relatively late in the evening, and thus avoids the twilight period (Rydell, Entwistle & Racey, 1996). It also avoids feeding in places with artificial lights (Rydell, 1992). We therefore expected this species to avoid moonlight, perhaps to a higher extent than the other species, but this was not the case. On the contrary, long-eared bats were sometimes identified (their ears were seen), when flying near the entrance in bright moonlight.

We can imagine three possible reasons why the bats at Taberg did not exhibit lunar phobia. These are not mutually exclusive. Firstly, temperate environments may perhaps support a smaller number of nocturnal predator species and particularly of species that specialize on bats, compared to the tropics. Tropical and temperate bats may have evolved different anti-predator behaviour if the underlying predator pressures differ. Perhaps predators at Taberg do not impose enough selection pressure to disrupt bat activity there. Secondly, aerial insectivorous bats are generally fast flying compared to frugivores (Norberg & Rayner, 1987) and may perhaps not be at risk when flying in moonlight. Frugivores and sanguivores, on the other hand, may be more

exposed in flight because they fly more slowly, especially to sit-and-wait predators when approaching the food sources among the vegetation or near the ground. Their flight style and feeding behaviour may therefore make them more susceptible to predators than aerial insectivores, and this could be the main reason for the lunophobic behaviour of some tropical bats (Morrison, 1978; Fleming, 1988). Thirdly, the bats at Taberg may have been prepared to face higher predation risks during the swarming and mating period, than they would have been otherwise, a situation common in animals (Alcock, 1997). The risk of missing mating opportunities may perhaps outweigh the risk of predation, if the latter is small. We cannot distinguish among these hypotheses with the data at hand.

Insectivorous bats generally avoid flying in daylight, because in bright light they are exposed to high predation risk from raptorial birds (Speakman, 1991b). Likewise, the timing of their evening emergence is constrained by the presence of raptorial birds which still may be active at dusk (Rydell *et al.*, 1996). On the other hand, at least some bat species (e.g. *Eptesicus* spp.) do not hesitate to expose themselves to light at night when foraging at streetlights (Rydell, 1992) or when swarming in moonlight (all species in this study). The difference may perhaps be that while the selection pressure from predators, e.g. hawks and falcons, in daytime and during dusk and dawn is high enough to influence bat behaviour drastically, predators that forage at night, e.g. owls and some mammals, do not constitute a significant threat to flying bats.

#### Acknowledgements

We acknowledge B. Lind, Södra Vätterbygdens Fågel-förening, for providing the bird list, L. E. Apelkvist for practical assistance and M. Augée, R. M. Brigham and M. B. Fenton for helpful comments and editing of the manuscript and J. Loman for statistical advice. The study was financed by the Swedish Natural Science Research Council (to JR).

#### REFERENCES

- Alcock, J. (1997). *Animal behaviour, an evolutionary approach*, 6th ed. Sunderland, MA.: Sinauer Associates.
- Brigham, R. M., Gutsell, R. C. A., Wiacek, R. S. & Geiser, F. (1999). Foraging behaviour in relation to the lunar cycle by Australian owl-nightjars *Aegotheles cristatus*. *Emu* **99**: 253–261.
- Degn, H. J., Andersen, B. B. & Baagøe, H. (1995). Automatic registration of bat activity through the year at Mønsted limestone mine, Denmark. *Z. Säugetierk.* **60**: 129–135.
- Fenton, M. B. (1969). Summer activity of *Myotis lucifugus* (Chiroptera: Vespertilionidae) at hibernacula in Ontario and Quebec. *Can. J. Zool.* **47**: 597–602.
- Fenton, M. B., Rautenbach, I. L., Smith, S. E., Swanepoel, C. M., Grosell, J. & van Jaarsveld, J. (1994). Raptors and bats: threats and opportunities. *Anim. Behav.* **48**: 9–18.
- Fleming, T. H. (1988). *The short-tailed fruit bat. A study in plant-animal interactions*. Chicago, IL: University of Chicago Press.

- Hartley, R. & Hustler, K. (1993). A less-than-annual breeding cycle in a pair of African bat hawks *Machaeramphus alcinus*. *Ibis* **135**: 456–458.
- Hecker, K. R. & Brigham, R. M. (1999). Does moonlight change vertical stratification of activity by forest-dwelling insectivorous bats? *J. Mammal.* **80**: 1196–1201.
- Horning, M. & Trillmich, F. (1999). Lunar cycles in diel prey migrations have a stronger effect on the diving of juvenile than adult Galápagos fur seals. *Proc. R. Soc. Lond. B. Biol. Sci.* **266**: 1127–1132.
- Jones, G. & Rydell, J. (1994). Foraging strategy and predation risk as factors influencing emergence time in echolocating bats. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **346**: 445–455.
- Kalcounis, M. C. & Brigham, R. M. (1994). Impact of predation risk on emergence by little brown bats, *Myotis lucifugus* (Chiroptera: Vespertilionidae), from a maternity colony. *Ethology* **98**: 201–209.
- Krzanowski, A. (1973). Numerical comparison of Vespertilionidae and Rhinolophidae (Chiroptera; Mammalia) in the owl pellets. *Acta Zool. Cracoviensia* **6**: 133–140.
- Morrison, D. W. (1978). Lunar phobia in a neotropical fruit bat, *Artibeus jamaicensis* (Chiroptera: Phyllostomidae). *Anim. Behav.* **26**: 852–855.
- Negraeff, E. & Brigham, R. M. (1995). The influence of moonlight on the activity of little brown bats (*Myotis lucifugus*). *Z. Säugetierk.* **60**: 330–336.
- Norberg, U. M. & Rayner, J. M. V. (1987). Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **316**: 335–427.
- Reith, C. C. (1982). Insectivorous bats fly in shadow to avoid moonlight. *J. Mammal.* **63**: 685–688.
- Ruprecht, A. L. (1979). Bats (Chiroptera) as constituents of the food of barn owls *Tyto alba* in Poland. *Ibis* **121**: 489–494.
- Rydell, J. (1991). Seasonal use of illuminated areas by foraging northern bats *Eptesicus nilssoni*. *Holarct. Ecol.* **14**: 203–207.
- Rydell, J. (1992). Exploitation of insects around streetlamps by bats in Sweden. *Funct. Ecol.* **6**: 744–750.
- Rydell, J., Entwistle, A. & Racey, P. A. (1996). Timing of foraging flights in three species of bats in relation to insect activity and predation risk. *Oikos* **76**: 243–252.
- Rydell, J., Gerell, R. & Apelkvist, L. E. (1999). Antalet övervintrande fladdermöss i gruvan i Smålands Taberg ökar. *Fauna flora, Stockholm* **93**: 107–112.
- Speakman, J. R. (1991a). The impact of predation by birds on bat populations in the British Isles. *Mammal Rev.* **21**: 123–142.
- Speakman, J. R. (1991b). Why do insectivorous bats in Britain not fly in daylight more frequently? *Funct. Ecol.* **5**: 518–524.
- Speakman, J. R., Stone, R. E. & Kerslake, J. E. (1995). Temporal patterns in the emergence behaviour of pipistrelle bats, *Pipistrellus pipistrellus*, from maternity colonies are consistent with an anti-predator response. *Anim. Behav.* **50**: 1147–1156.
- Thomas, D. W., Fenton, M. B. & Barclay, R. M. R. (1979). Social behaviour of the little brown bat, *Myotis lucifugus*. *Behav. Ecol. Sociobiol.* **6**: 129–136.
- Turner, D. C. (1975). *The vampire bat. A field study in behavior and ecology*. Baltimore: Johns Hopkins University Press.
- Usman, K., Habersetzer, R., Subbaraj, R., Gopalkrishnaswamy, G. & Paramandam, K. (1980). Behaviour of bats during a lunar eclipse. *Behav. Ecol. Sociobiol.* **7**: 79–80.
- Wai-Ping, V. & Fenton, M. B. (1988). Nonselective mating in little brown bats (*Myotis lucifugus*). *J. Mammal.* **69**: 641–645.
- Wai-Ping, V. & Fenton, M. B. (1989). Ecology of spotted bat (*Euderma maculatum*) roosting and foraging behavior. *J. Mammal.* **70**: 617–622.
- Whitaker, J. O., Jr. & Rissler, L. J. (1992). Seasonal activity of bats at Copperhead mine. *Proc. Indiana Acad. Sci.* **101**: 127–134.