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The influence of moonlight on the activity of Little brown bats (*Myotis lucifugus*)

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Abstract

Lunar cycles influence the activity patterns of a variety of organisms including marine fish, rodents, birds, and fruit-eating bats. Lunar light, specifically a full moon, has also been suggested to depress the activity of insectivorous bats, because of increased predation risk or decreased insect prey abundance. These observations are generally anecdotal, however, with few quantitative data to support or refute them. The purpose of our study was to measure activity of little brown bats (*Myotis lucifugus*) in relation to the lunar cycle, and other environmental conditions, (e. g., ambient temperature, cloud cover, and wind strength). If bats are "lunar phobic" for predator avoidance reasons, then activity levels should decrease or shift to more sheltered habitats. We used ultrasonic bat detectors to assess bat activity. Counter to our prediction, the percent moon face illuminated did not significantly predict bat activity levels. There was also no evidence of a habitat shift correlated with lunar light levels. Activity was significantly related only to ambient temperature, a result commonly found in other studies. Our results indicate that insectivorous bats are not lunar phobic, implying they do not experience substantially higher predation risk or lower prey availability during moonlit periods.

Introduction

Exogenous factors such as photoperiod, temperature and light levels often influence biological rhythms in animals. Rhythms influenced by light are said to follow a lunar cycle if the maxima or minima of the rhythmic activity appears once in a lunar month (Saigusa and Hidaka 1978). Many vertebrate animals incorporate a lunar cycle into their activities, including marine fish (Robertson et al. 1990), rodents (Lockard and Owings 1974; Wolfe and Summerlin 1989; Kotler et al. 1991; Daly et al. 1992), nocturnal birds (Mills 1986; Brigham and Barclay 1992), and frugivorous bats in the laboratory (Häussler and Erkert 1978) and under natural conditions (Erkert 1974; Morrison 1978, 1980). Not surprisingly, nocturnal birds and visually orienting bats become more active during the brightest portions of the lunar cycle when visual sensitivity is increased (Martin 1990). All else being equal, foraging by insectivorous bats, which rely on echolocation, should not be effected by lunar light conditions. To date, the few studies done have reached equivocal conclusions (Erkert 1982).

Two hypotheses have been proposed to explain why insectivorous bat activity may be depressed during the bright phase of the lunar cycle. First, there may be a higher risk of predation from visually orienting predators. During moonlit periods, terrestrial animals reduce activity or choose to occupy more cluttered habitats which presumably provide more cover (birds: Imber 1975; Storey and Grimmer 1986; Watanuki 1986; Nelson 1989 and rodents: Kotler 1984; Price et al. 1984; Longland and Price 1991; Dickman 1992).

If bats exhibit "lunar phobia" in response to increased predation risk, then activity levels should decline with increasing levels of moonlight or increase in "safer" habitats (Reith 1982).

The second hypothesis is that flying insect abundance is depressed during the bright part of the lunar cycle. If this is true, then bats may be less active on moonlit nights because it is energetically unfavourable to forage, especially when they can enter torpor to save energy (Audet and Fenton 1988). In other words, bats may not themselves be lunar phobic, but simply react to a lunar effect on insects.

The objective of this study was to evaluate the hypothesis that activity by little brown bats (*Myotis lucifugus*) is depressed by increasing levels of lunar light. If bats alter activity patterns to avoid visually orienting predators, activity should decline with increased lunar light levels or shift to habitats with more "cover". Records of night roost use suggest that the activity of *M. lucifugus* is not influenced by lunar conditions (Anthony et al. 1981), however no direct measurement of foraging activity has been made.

The little brown bat is a small insectivorous bat (6–11 g; van Zyll de Jong 1985; Nagorsen and Brigham 1993) which ranges over most of North America. It is the most common species captured in the Cypress Hills (Kalcounis and Brigham 1995), although other *Myotis* spp. do occur. *Myotis lucifugus* consumes small (3–10 mm long) flying insects, usually from the orders Coleoptera, Diptera, Ephemeroptera, Homoptera, Isoptera, Lepidoptera, and Trichoptera (Fenton and Barclay 1980).

Material and methods

The study was conducted from May–August 1992 in the West Block of the Cypress Hills Provincial Park (49°34′N, 109°53′ W) in southwestern Saskatchewan. Local vegetation is a mixture of forest and grasslands with the forest consisting of white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), and trembling aspen (*Populus tremuloides*). Battle Creek, its tributaries, and small beaver (*Castor canadensis*) ponds are the main water bodies in the area. The area was a particularly suitable location for this study because there are virtually no artificial light sources.

We monitored bat activity at one site in each of three habitat types; over water, over open fields, and in *P. glauca* forests. These habitats represent those regularly used by *M. lucifugus* (Kalcounis and Brigham 1995) in the study area. We quantified activity by using ultrasonic bat detectors (Ultrasound Advice, 23 Aberdeen Road, London N5 20G, U.K.) set at 42 kHz, the peak frequency used by *M. lucifugus* (Thomas et al. 1987). The detectors allowed us to separate bat passes (calls made by commuting bats) from feeding buzzes (calls produced in association with attacks on prey; Griffin et al. 1960). To assess activity over water (slow moving sections of Battle Creek), the detector was angled over the water from the creek bank; in field and forest habitats the detector was pointed directly upwards.

We counted the number of passes or feeding buzzes heard in 5-minute intervals during "true night", i.e., the time between the end of nautical twilight in the evening and the beginning of nautical twilight in the morning when the sun is 12° below the horizon (Hagen and Boksenberg 1990). We monitored activity for at least one hour at the beginning and one hour at the end of true night. We chose these periods since they represent the times when the bats were most active overall (Kalcounis and Brigham 1995). Light sources were turned off for at least 2 minutes prior to and during all sampling intervals to minimize any effect of light on insects in the vicinity.

The percentage moon face illuminated (%MFI) was used as an index of lunar light (Hagen and Boksenberg 1990; Brigham and Barclay 1992). Bat activity was measured only if the moon was above the horizon, unless %MFI was $<5\%$. Low %MFI moons are rarely above the horizon during true night and these periods were defined as having 0 %MFI. Collecting data during true night periods when %MFI is low is difficult because of the short period of time the moon is up (Martin 1990). Times for moonrise and moonset, and the end and beginning of nautical twilight were calculated for the study site by the Dominion Astrophysical Observatory (Victoria, B.C.).

Cloud cover, wind strength, precipitation in the form of rain, and ambient temperature were recorded at the end of each sampling period. Cloud cover and wind strength were rated subjectively on a scale of 0–3, with 0 representing no wind or cloud and 3 meaning 100% cloud cover or very strong winds (>30 km/hr). Precipitation was recorded as yes or no and temperature was measured using a telethermometer located within 5 km of all sampling sites.

Stepwise multiple regression analysis was used to determine if bat activity was related to % MFI and ambient temperature; cloud cover and wind speed did not vary enough to be included in the model. Activity in the three habitat types was analyzed using ANOVA to determine if activity changed with respect to lunar light, classified as (0–25%, 26–50%, 51–75%, 76–100%MFI). Results are presented as means ± 1 SE and a 0.05 rejection criterion was employed for all tests.

Results

We sampled bat activity on 36 nights between 20 June and 28 August (approximately 3 full lunar cycles) for a total of 628 five-minute intervals. This included 440, 142, and 46 intervals in the water, field and forest habitats, respectively. Cloud cover obscured a substantial amount of sky on only 3 nights (cloud cover index >1). Two of these nights were accompanied by moderate temperatures with no rain or wind. Activity occurred in both cases, despite the fact that one night had a low %MFI (0%) and the other had a high %MFI (99%). The third cloudy night was relatively cool (2 °C), with strong winds (wind strength = 2) and rain, and no bat activity occurred.

Overall, activity levels were low and feeding buzzes accounted for <5% of all activity. We therefore combined passes and buzzes for all analysis. Bats were significantly more active in the over water habitat ($F = 26.21$, $df = 2$, $p < .001$), than in the field or forest habitats which is why we concentrated our sampling efforts in that habitat. Ambient temperature was a significant predictor of bat activity ($r^2 = 0.14$, $P < 0.05$; Fig. 1), but %MFI was not (Fig. 2). There was no evidence of an relationship between activity and lunar light levels in any of the 3 habitats (Water: $F = 2.55$; Field: $F = 2.91$; Forest: $F = 2.23$; $df = 3$ and $P > 0.05$ in all cases).

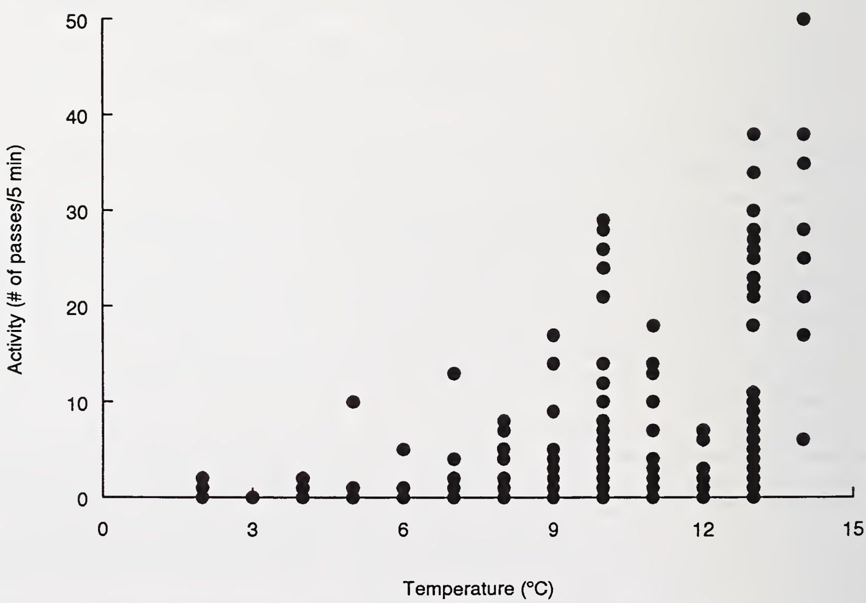

Fig. 1. Bat activity levels (# of bat passes/5 minutes) as a function of ambient temperature (°C) for data from water habitat.

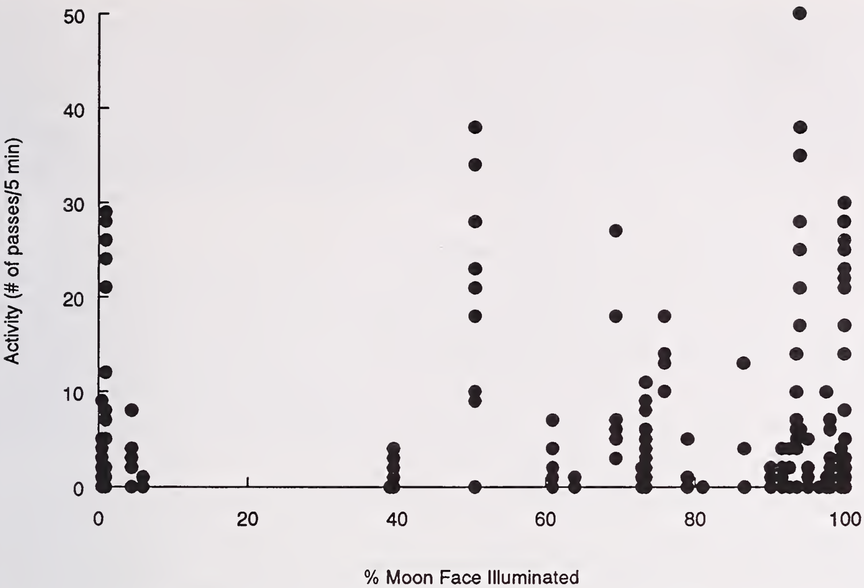

Fig. 2. Bat activity levels (# of bat passes/5 minutes) as a function of percentage of moon face illuminated (%MFI) for data from water habitat.

Discussion

Our results indicate that %MFI is not a significant predictor of *M. lucifugus* activity, although it has been shown to predict activity in other animals such as insectivorous birds (Mills 1986). Erkert (1974) and Morrison (1978; 1980) demonstrated that visually orienting frugivorous bats display lunar phobia, and argued that the behaviour likely evolved in response to increased predation pressure during the brightest portion of the lunar cycle. However, because of the absence of predators, bats in temperate locations may not have evolved such a response. Baker (1962) argued that nocturnal birds of prey (e. g., owls), the most likely predators on bats, are incapable of the flight manoeuvres required to capture bats regularly. This may explain anecdotal reports which indicate lunar effects have no influence on bat activity (Bell 1980; Bradbury and Vehrencamp 1976; Leonard and Fenton 1983; Kronwitter 1988; Wai-Ping and Fenton 1989).

Myotis lucifugus did not demonstrate a habitat shift from open to covered habitats in response to increasing lunar light levels unlike rodents (Daly et al. 1992) and birds (Watanuki 1986). Reith (1982) concluded that *Myotis yumanensis* used shadows more during moonlight conditions, but his data were collected on only 7 nights during one month. Clark et al. (1993) commented that in bright moonlight *Plecotus townsendii* foraged adjacent to vertical surfaces such as trees and cliffs, but presented no quantitative data. At our study site, habitat shifts are known to occur, but apparently for aerodynamic reasons as a result of fluctuations in body mass (Kalcounis and Brigham 1995). However, because activity did not decrease in bright moonlight, the lack of evidence for a habitat shift is not surprising. That activity in the water habitat was higher than the field or forest reinforces the findings of other studies on activity patterns of this species (Fenton and Barclay 1980).

There is considerable debate in the literature as to whether the lunar cycle influences flying insect activity. Evidence for a lunar effect on insect abundance may be due to decreased light trap effectiveness during moonlit periods (Siddorn and Brown 1971). Williams and Singh (1951) used alternative attractants and did find a lunar effect on insect abundance. Conversely, Bidlingmayer (1964), Bowden and Morris (1975), Williams et al. (1956), and Hardwick (1972) found that insect densities either increased or did not change during the period of the full moon. When taken in combination these studies suggest that the effect of the lunar cycle is likely species specific (Brown and Taylor 1971; Taylor 1986), and the effect on overall prey abundance for bats may be negligible which would concur with our activity results.

Ambient temperature was a good predictor of bat activity levels, an idea widely reported in the literature (e.g., O'Farrell and Bradley 1970). Temperature is presumed to have mostly indirect effects on bat activity because low ambient temperatures decrease flying insect activity (Taylor 1963; Mcgeachie 1989; Danthanarayana and Gu 1992).

Cloud cover, strong winds, and precipitation were rare during our sampling, and thus, not important factors influencing activity. The one cloudy night which had no bat activity also had a low ambient temperature. Cloud cover does not appear to affect activity levels of birds (Mills 1986) or bats (Leonhard and Fenton 1983), even for those bats which do exhibit lunar phobia (Morrison 1978).

Although it is likely that we only detected *M. lucifugus* in this study, it is possible that other insectivorous bats were also sampled. Ultrasonic bat detectors provide a simple and inexpensive means for monitoring bat activity without the need for catching, and thus potentially disturbing bats. However, the detectors we used only provide information on an approximate 3 kHz window at one time (Thomas and West 1984), and do not allow for unambiguous species identification. The next step is to use radio-telemetry and directly assess the activity patterns of known individuals with respect to the lunar cycle (e.g., Brigham and Barclay 1992).

To maximize fitness, animals should increase the benefits of activity (which is often associated with feeding) while reducing the costs associated with activity. Since little brown bats do not reduce activity levels during the brightest part of the lunar cycle, we infer that they do not experience significant costs, either in terms of increased predation risks or decreased prey levels, during periods with lunar light.

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Zusammenfassung

Der Einfluß von Mondlicht auf die Aktivität der kleinen braunen Fledermaus Myotis lucifugus.

Die Mondphasen beeinflussen das Aktivitätsmuster einer Reihe von Organismen, u.a. von Meeresfischen, Nagern, Vögeln sowie frugivoren Fledermäusen. Es wird ferner angenommen, daß Mondlicht, insbesondere Vollmond, die Aktivität insektivorer Fledermäuse aufgrund erhöhter Predationsgefahr oder geringerer Verfügbarkeit von Beute vermindert. Die zugrundeliegenden Beobachtungen sind jedoch im Allgemeinen Einzelfälle, und die wenigen vorhandenen quantitativen Daten können die Annahme weder erhärten noch widerlegen. Das Ziel unserer Untersuchung war, das Verhältnis der Aktivität von *Myotis lucifugus* zum Mondzyklus und anderen Umweltbedingungen, z.B. Umgebungstemperatur, Bewölkungsgrad, Windstärke, zu bestimmen. Sind Fledermäuse „mondscheu", um Predatoren zu entgehen, sollte ihre Aktivitätsintensität abnehmen oder sie sollten in geschütztere Habitate ausweichen. Wir verwendeten Ultraschallempfänger, um die Fledermausaktivität zu messen. Entgegen unserer Annahme bestand kein signifikanter Zusammenhang zwischen Mondphase und Fledermausaktivität. Es gab auch keine Anzeichen für einen Habitatswechsel in Abhängigkeit von der Mondphase. Die Aktivität korrelierte einzig mit der Umgebungstemperatur, ein Ergebnis das auch in anderen Untersuchungen häufig gefunden worden ist. Unsere Ergebnisse zeigen, daß insektivore Fledermäuse nicht mondscheu sind und daß sie bei hellem Mondlicht weder stärkerer Predation ausgesetzt sind, noch die Verfügbarkeit von Beute eingeschränkt ist.

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