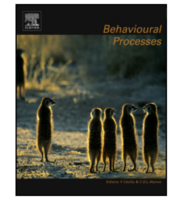
Behavioural Processes 100 (2013) 131–138

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc



Roost selection by female Hemprich's long-eared bats

Carmi Korine*, Shai Daniel, Berry Pinshow

Mitrani Department of Desert Ecology, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, 84990 Midreshet Ben-Gurion, Israel

ARTICLE INFO

Article history:
Received 1 June 2013
Received in revised form 18 August 2013
Accepted 19 August 2013

Keywords:
Desert
Lactation
Otonycteris hemprichii
Reproduction
Roost characteristics
Temperature

ABSTRACT

Selection of suitable roosts by bats can have fitness benefits by providing shelter and a place to rear young. Assuming that lactating bats behave differently from, and have greater food requirements than pregnant bats, we predicted that near the end of pregnancy, desert-dwelling bats would move to roosts appropriate to their changing needs. We followed radio-tagged pregnant and lactating female Hemprich's long-eared bats, *Otonycteris hemprichii*, to their roosts and characterized the shape of 38 roosts by measuring their linear dimensions, compass direction of the outer rock face, roost temperature (T_r) and the distance from the roost to the bats' main foraging site. We also compared roosts used by bats to randomly chosen "potential" roosts. During reproduction, female *O. hemprichii* roosted mainly in cracks. Throughout the bats' reproductive period, most of the roosts faced the morning sun. Temperatures in roosts used by pregnant bats or distances to their main foraging site were not different from those used by lactating individuals. However, pregnant females used horizontal cracks while lactating females used vertical cracks. Comparing roosts used by bats to "potential" roosts, we found that the former had smaller daily amplitudes of T_r than the "potential" ones. Female *O. hemprichii* used only a small number of the available roosts in the area, and re-used some of them year after year. We suggest that, in contrast to bats that live in temperate habitats, *O. hemprichii* do not need to seek roosts with temperature conditions specific to the periods of pregnancy or lactation because natural changes in T_r suffice, and other factors are involved in the decision to choose a roost or to abandon it.

1. Introduction

Many species of bat prefer roosts with relatively high internal temperatures (T_r) and a temperature gradient within the roost that can be used to advantage by moving within the roost according to the animal's thermal needs (Kunz and Lumsden, 2003). In the absence of a temperature gradient within a roost, bats can modify the microclimate of their surroundings by either changing roost site or by huddling (Burnett and August, 1981; Roverud and Chappell, 1991; Willis and Brigham, 2007). In addition, the presence of a large number of individuals likely brings about an increase in T_r. These patterns of behavior help bats realize the optimal temperature needed for rapid growth of their offspring (McNab, 1982; Williams and Brittingham, 1996; Entwistle et al., 1997; McLean and Speakman, 1999; Kerth et al., 2000; Willis and Brigham, 2007).

A roost with sustained, high T_r saves euthermic bats energy (Chruszcz and Barclay, 2002). For example, the energy cost for a lesser long-eared bat (*Nyctophilus geoffroyi*) to be euthermic at thermoneutrality (measured at an air temperature (T_a) > 30 °C) is 3.75 times less than at T_a = 20 °C, i.e. 0.0472 W and 0.175 W, respectively (Geiser and Brigham, 2000). To keep body temperature (T_b) above a lower limit at all times, some bats have no choice but to select roosts with a T_r as high as 50 °C for part of the day (Bronner et al., 1999). Entwistle et al. (1997) goes as far as to suggest that the presence or absence of roosts with high T_r can limit the dispersal of a species or even limit its population size. For lactating females, the benefit of using warm roosts is even greater than for non-reproductive females, or for males, due to their responsibility for the thermoregulation of their offspring as well as for their own (Lewis, 1996).

In addition, other factors such as color of the external walls of a roost may affect roost selection, as was demonstrated for bat boxes (Kerth et al., 2000). Indeed, several reports have inferred selection for specific microclimate properties by comparing active and available roosts in the field (Willis and Brigham, 2005; Sedgeley, 2006; Goldingay, 2009; Campbell et al., 2010).

In light of the above, we hypothesized that roost preference of female bats during reproduction is shaped by a trade-off between the acquisition of energy through food consumption and roost temperature requirements for embryo/pup growth and the mother's need to use torpor to save energy and water. We suggest that this may be particularly important in bats that roost alone or in small groups in rock crevices, especially in the desert, where days are hot

* Corresponding author at: Jacob Blaustein Institutes for Desert Research, 84990 Midreshet Ben-Gurion, Israel. Tel.: +972 8 6596773; fax: +972 8 6596772.
E-mail address: ckorine@bgu.ac.il (C. Korine).

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http://dx.doi.org/10.1016/j.beproc.2013.08.013

and nights are considerably cooler during the summer reproductive period.

We tested the following predictions stemming from our hypothesis using female Hemprich's long-eared bats, *Otonycteris hemprichii*, because they roost in small groups in cracks in rock faces (Daniel et al., 2010a,b): (1) female bats choose roosts with relatively low T_r at the beginning of pregnancy when prey availability is low, but move to roosts with higher T_r toward the end of pregnancy and during lactation when prey availability is high; (2) bats use roosts with larger diurnal amplitudes in T_r during pregnancy than during lactation; and (3) bats use roosts that are closer to their main foraging site during lactation than during pregnancy to reduce costs of flights and travel distances to their pups.

2. Materials and methods

2.1. Research area

Our study was done in the Central Negev Highlands in the proximity of Midreshet Ben-Gurion (30°52′N, 34°47′E), in the areas around Yeruham Reservoir (surface area ∼3 Ha, with surrounding plantations, 30°59′N, 34°53′E) and the Machtesh Gadol (30°57′N, 34°57′E, Fig. 1A and B). The Central Negev Highlands are defined as arid (precipitation to potential evapotranspiration ratio (P/ETP) ranging from 0.03 to 0.2) to hyper-arid (P/ETP < 0.03) (UNESCO, 1979; Bruins and Berliner, 1998). Rain in the central Negev highlands falls during winter, with great variation in total precipitation and in temporal and spatial distribution (Zangvil, 1996). Air temperatures are highest during summer, with a daily mean of 25.3 °C in August and a mean maximum temperature of 32.2 °C and lowest in winter, with a daily mean of 9.7 °C and mean minimum temperature of 3.6 °C in January (Meteorology Unit, Department of Solar Energy and Environmental Physics, Jacob Blaustein Institute for Desert Research).

Bats were caught in mist nets at known foraging sites from March to October in 2002, 2003 and 2004 (Korine and Pinshow, 2004). We recorded sex, reproductive status mass and forearm length. We characterized reproductive status from abdomen size and shape and nipple condition and by examining the bats in the laboratory (Daniel et al., 2010b). We found pregnant female *O. hemprichii* from the beginning of March until the end of May, while the lactation period lasted from the beginning of June to the beginning of August (Daniel et al., 2010a,b). We also found that during pregnancy and lactation, female bats roosted in small groups of 2–5 individuals, in some cases pregnant females roosted alone and, during lactation female bats roosted without males (Daniel et al., 2010a).

Individuals were marked either with a five-digit tattoo on the wing, or with a passive integrated transponder (PIT) tag that weighed 0.1 g and was inserted between the shoulder blades (Trovan® Electronic Identification System LTD., UK, model ID-100).

2.2. Radio telemetry

We radio tagged all the female *O. hemprichii* that we captured and, when we found a roost, we recorded its location using a GPS device (eTrex®, Garmin International Inc., KS, USA). To attach a radio transmitter to a bat's back, a small area of fur between the shoulder blades was shaved and the radio transmitter was glued in place with Skin-bond Cement® (Smith & Nephew United Inc., Largo, Florida, USA). We used crystal-controlled radio transmitters that weighed 1–1.2 g (Holohil Systems, Canada, model BD-2T) to locate the bats. The mass of a transmitter was not more than 5% of the mass of any bat. This has been shown not to interfere with the bat's behavior in general (Aldridge and Brigham, 1988). Transmitter-equipped bats were released at their site of capture within 2 h, after verifying that the transmitter was fully functional and properly attached to the bat.

A pair of observers tracked each released bat with logging telemetry receivers (Lotek Engineering Inc., Ontario, Canada, model SRX 400, or H.A.B.I.T. Research, Ltd., Victoria, BC, Canada model HR2000 OSPREY). The bats were tracked from their release point until a roost site was located. The transmitters remained in place between 7 and 17 days and fell off by themselves. In a preliminary laboratory trial, we did not detect any adverse effect of radio tagging on the bats. Body mass was stable and the bats showed no external sign of having carried a transmitter (Daniel et al., 2010b). In addition, several radio tagged bats and their pups were recaptured in subsequent years, suggesting that radio tagging did not affect survival.

2.3. Roost data collection

Functionally, we divided the roosts into three groups based on the actual reproductive period of the tracked animal, which we named pregnancy (P), lactating (L), and P&L (roosts used during both pregnancy and lactation). We measured physical characteristics of the roosts, namely, depth, entrance height (defined from the bottom to the top point of the entrance), distance of the entrance from the ground with a tape measure, and compass direction of the slope face and its vertical angle with a compass *cum* clinometer (pocket transit model 2061, Brunton, Riverton, WY, USA). We classified all the roost into five structural types: (1) cavities; (2) crevices in a rock walls; (3) holes in rock shelves at ground level (with an area of ground below the entrance of at least 5 m^2); (4) crevices in shallow, cave-like erosion structures; or (5) crevices in isolated rocks (Fig. 2). We further categorized the roosts into four groups by internal shape and entrance type: (1) vertical with side entrance; (2) vertical with bottom entrance; (3) horizontal with side entrance; or (4) horizontal with bottom entrance.

Roost temperatures were measured with iButton® data loggers (Dallas Semiconductor, Maxim Integrated Circuits, Dallas, TX, USA) placed near the roosting bats in a total of 26 active roosts, near the roosting bats. Distances from the entrance of each occupied roost to the main foraging and drinking sites and between different roosts, entrance to entrance, were measured with either a tape measure or using a topographical map. Data were collected only from roosts occupied for ≥24 h by the tagged bat.

2.4. Roost characterization: comparison between used roosts and "potential" roosts

One of our objectives was to ascertain whether female *O. hemprichii* select roosts non-randomly, and to determine the important physical characteristics of the selected roosts. To do this, around each of the occupied roosts, at 5 m distance we randomly, without *a priori* assumptions, chose up to four crevices or holes of 10 cm or more in depth, based on the characteristics of occupied roosts, that we refer to as "potential" roosts. If we found more than one "potential" roost in the same direction and at the same distance, we chose between them randomly, by the throw of a die. All measurements of the "potential" roosts were made exactly as described for active roosts. To compare T_r between the active and the "potential" roosts, we inserted iButton® data loggers in "potential" roosts around nine active roosts.

Data were compared using ANOVA, Student *t*-tests, χ^2 tests, Tukey–Kramer honestly significant difference (HSD) all pair