The use of exposed diurnal roosts in Alberta by the little brown bat, *Myotis lucifugus*

Daniel K. Riskin and Margo J. Pybus

Abstract: The use of exposed diurnal roosts by the little brown bat, *Myotis lucifugus,* throughout the summer months is only known to occur among Alberta populations of this species. This study is the first to examine that behaviour. In total, 426 *M. lucifugus* using exposed anthropogenic surfaces as diurnal roosts were observed in the summers of 1985 and 1986. Bats were usually found alone, but groups of up to six individuals were seen. When found at these roosts, 98.8% of bats were at least 2 m from the ground and 95.1% were below an overhang. Bats were found on brick substrates in 89.0% of observations and in the corner between two surfaces in 57.0%. Bats were found on east-facing surfaces less frequently than expected under random distribution. Roost selection appears to have been based on several strategies, including thermoregulation, predator avoidance, and desiccation avoidance. After maternity roosts were vacated, the proportion of juveniles at exposed roosts was higher than their proportion in the total population. This may be the result of their inability to enter, or lack of knowledge of, many enclosed roosts used by adults.

Résumé : Chez le Vespertilion brun, *Myotis lucifugus,* l'utilisation de dortoirs de jour à découvert au cours des mois d'été n'a été observée que chez les populations d'Alberta. Au total, 426 vespertilions ont été observés au repos sur des surfaces anthropogéniques au cours de la journée au cours des étés de 1985 et 1986. Les chauves-souris étaient généralement seules, mais des groupes pouvant contenir jusqu'à six individus ont été vus. Dans ces dortoirs, 98,8% des vespertilions étaient à au moins 2 mètres du sol et 95,1% se trouvaient sous une surface en surplomb. Les chauves-souris ont été trouvées sur un substrat de brique dans 89,0% des cas et dans l'angle entre deux surfaces dans 57,0% des cas. Il y avait moins de chauves-souris sur les surfaces orientées vers l'est que le nombre auquel on s'attendrait dans le cas d'une répartition aléatoire. Le choix d'un site de repos semble relever de plusieurs stratégies reliées à la thermorégulation, à la fuite des prédateurs et à l'évitement de la dessiccation. Après l'évacuation des pouponnières, la proportion des juvéniles aux dortoirs à découvert était plus élevée que leur proportion au sein de toute la population. Peut-être faut-il voir là le résultat de l'incapacité des juvéniles d'avoir accès aux dortoirs protégés utilisés par les adultes, ou peut-être est-ce le résultat de la diminution du nombre des adultes qui ont quitté les lieux pour gagner leurs hibernaculums.
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Introduction

The establishment of summer roosts within buildings by little brown bats (*Myotis lucifugus*) is well documented (Fenton and Barclay 1980; Kalcounis and Brigham 1994). The exposed sides of buildings were also thought to be used as roosts, but only briefly after the breakup of maternal colonies, and only by juveniles (Fenton and Barclay 1980). However, much information on the roost ecology of this species is lacking. Since the 1970s, cooperative programs conducted on the species by Alberta Fish and Wildlife and Alberta Agriculture, Food and Rural Development have been aimed at describing and understanding its life history within the province. One such study (Showalter et al. 1979) made note of little brown bats on the exterior surfaces of buildings in Alberta during summer days. That study did not provide further information regarding such roosts. This behaviour has not been described in any other populations of *M. lucifugus*, despite extensive studies elsewhere in the species' range (Davis and Hitchcock 1965; Dalquest and Walton 1970; Humphrey and Cope 1976). This paper is the first to describe the ways in which *M. lucifugus* has adapted to exposed diurnal roosts in Alberta.

Received June 11, 1997. Accepted October 21, 1997.

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Methods

Study site

Observations were made across rural and urban regions of central Alberta, but were concentrated between latitudes 52° and 55°N and longitudes 110° and 115°W. The occurrence of bats on the exposed sides of anthropogenic structures was recorded. Forested areas were not examined. Use of exposed diurnal roosts by little brown bats over two summers was observed by employees of Alberta Fish and Wildlife, under the direction of M.J. Pybus.

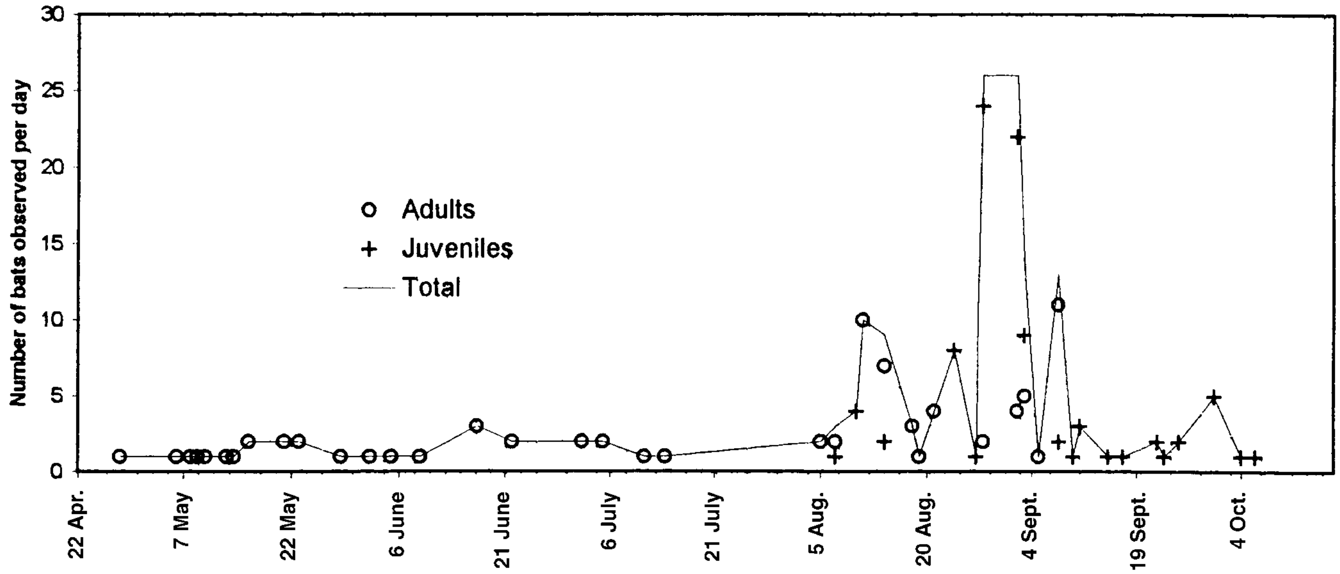
Subspecies classification

All bats described in this study were probably members of the subspecies *Myotis lucifugus lucifugus* (LeConte). All observations were made north of the range of *Myotis lucifugus carissima* Thomas, Alberta's only other non-mountain-dwelling subspecies of *M. lucifugus* (Smith and Schowalter 1979). Schowalter et al. (1979) suggested that *M. l. carissima* in Alberta does not use exposed diurnal roosts.

Observing bats

Bats were observed from mid-August to mid-October 1985 and from late April to late October 1986. Searches, made throughout daylight hours, were mostly concentrated between 07:00 and 10:00. The date

Fig. 1. Number of little brown bats (*Myotis lucifugus*) observed per day at exposed roosts through the summer of 1986 in Alberta. Note that as the ages of all bats were not recorded, the total number of bats seen per day is not necessarily the sum of juvenuiles and adults.



and presence or absence of an overhang above the bat were recorded, as were the substrate and aspect (estimated to the nearest cardinal direction, north, south, east, or west) of the roost surface. The distance of the animal from the ground was estimated visually to within 0.5 m. Where possible, bats were handled to resolve age (juvenile or adult), as determined from the epiphyseal closure of the digits (Fenton and Barclay 1980), and gender. Group sizes were also recorded. Bats that appeared to be in exactly the same location on consecutive days were counted only once. Data for all parameters were not recorded at every sighting, so sample sizes (*n*) vary among criteria.

Statistical analysis

A χ^2 test using Yates' correction for continuity (χ_c^2) (Zar 1996) was employed to compare the abundances of bats on the four aspects versus other surfaces, using a 1:3 ratio as the null hypothesis.

Results

The occurrence of a little brown bat on an exposed building wall was documented 426 times. All bats were stationary and many appeared torpid. Age was determined in 62.9% of the bats encountered and sex in 74.6%. While adults occurred at exposed roosts from late April to early October, juveniles only appeared between August and October (Fig. 1). After August 4, the 134 juveniles observed significantly outnumbered the 69 adult females seen at exposed roosts ($\chi_c^2 = 20.177$, $P < 0.01$, $n = 203$). Adult females, constituting 61.1% of adults observed prior to August 4, did not significantly outnumber males ($\chi_c^2 = 0.5$, $P > 0.05$, $n = 18$), but after that date, females were significantly overrepresented (65.7%) among adults ($\chi_c^2 = 9.752$, $P < 0.05$, $n = 105$). Only in 1986 were observations made before August 4, so seasonal aspects of roost use are based on 1986 data alone (Fig. 1).

Bats chose roosting sites 2 m or more above the ground in 98.8% of instances ($n = 424$). The maximum and minimum heights recorded were 0.1 and 7.5 m, respectively. Bats were found beneath an overhang between 0.1 and 10 m long in 95.1% of observations ($n = 410$), and tightly tucked into an inward-facing (≤90°) corner in 57.0% ($n = 405$). Generally, bats occurred at the top of a wall, alcove, or window frame directly below the overhang. Most (89.0%) bats were found on brick surfaces ($n = 426$). Of these, 90.2% were on rough brick as opposed to brick of smooth or intermediate texture, and 95.5% were on dark (red or brown) brick ($n = 379$). Other substrates used included stucco (3.3%), concrete (2.3%), stone (2.3%), metal (2.1%), and wood (0.5%). Although the relative availability of these substrate types in the environment was not measured, brick is a rare building material within the study area, and was estimated to have constituted only 10–20% of the available exterior building surfaces. Seventy-two percent of the bats occurred alone ($n = 426$); however, groups of two (12%), three (5%), four (3%), five (2%), and six bats (1%) were also recorded. Bats occurred less frequently on east-facing surfaces than expected in a random distribution, but occurred randomly on surfaces facing in the other three cardinal directions (Table 1).

Table 1. Deviation from random distribution of little brown bats (*Myotis lucifugus*) on surfaces with four different aspects.

	North	South	East	West
Number of bats ($n = 426$)	119	119	85	103
χ_c^2 (aspect vs. other 3 aspects)	1.80	1.80	5.52	0.11
Significant ($P < 0.05$)?	No	No	Yes	No

Note: Deviation was measured individually with a χ^2 test, using Yates' correction for continuity (χ_c^2).

Discussion

Maternal colonies of females and young little brown bats occur within enclosed roosts such as caves, trees, or buildings (Dalquest and Walton 1970; Humphrey and Cope 1976). The high number of juveniles and adult females at exposed roosts in late summer suggests that these sites are selected over the enclosed maternal colonies used earlier in the season. Further, the data presented in this study suggest that *M. lucifugus* exhibit a preference when selecting exposed roosting sites. We suggest that exposed roosts are selected that provide security from predation and physiological stress.

The presence of an overhang appeared to be the most favoured characteristic of an exposed roost. An overhang may provide visual protection from flying predators such as owls (Kalcounis and Brigham 1994) and black-billed magpies (*Pica pica*) (Boxall 1982; Hochachka and Scharf 1986), which commonly prey on the species. In addition, overhangs may shelter bats from precipitation and may offer some shelter from desiccation in the midday sun. Exposure to sunlight would increase heat gain through solar radiation and thus decrease the energy-conserving benefits of torpor, a strategy employed by *M. lucifugus* on cool days, particularly in late summer (Fenton 1970).

A position well above the ground was the second most important characteristic determining use of exposed roosts. Although potential roosting sites were available over a wide range of heights, most bats were found more than 2.0 m from the ground. This may reflect avoidance of terrestrial predators, including house cats, which often prey on little brown bats (Fenton and Barclay 1980). Also, the utilization of free-fall by *M. lucifugus* in attaining flight velocity (Powers et al. 1991) may be a determinant of their preference for elevated roosts.

The bats were commonly found tucked deeply into corners. Although the availability of corners was not measured directly, it can be assumed that significantly more non-corner roosts were available than corner roosts. Corners may make bats less conspicuous to visual predators and perhaps more difficult for aerial predators to glean. Corners may also protect bats from the thermoregulatory stresses associated with heat loss from wind and precipitation and heat gain from solar exposure.

Bats were most commonly found on brick, usually of a dark colour and rough texture. Rough surfaces would seem to provide an optimum surface upon which to cling. Although wood is also rough and was readily available, bats were rarely observed using it in this study. In a comparison of wooden with concrete bat houses in Sweden, Gerell (1985) noted that during cold periods, concrete bat boxes were more commonly occupied than wooden ones. Similarly, the predominance of brick as the material of exposed roosts in Alberta may reflect an affinity of bats for substrates of high heat capacity in late summer. Schowalter et al. (1979) also noted that brick was the most common substrate of exposed roosts. However, since the range of roosts available was not recorded in either study, it is not possible to quantify the degree of selection of brick by *M. lucifugus*.

Bats in our study and that of Schowalter et al. (1979) were usually torpid, and did not adjust their position throughout the day. Thus, the locations occupied by bats throughout the day were likely selected in the earliest morning. The significant avoidance of east-facing surfaces in favour of the other three aspects combined may represent an aversion to roosts exposed to the light and heat radiated by the sun at dawn. The decreased exposure to solar heat would increase the net benefit of torpor. Little brown bats commonly use non-exposed diurnal roosts with a southwesterly exposure, which provides increased solar heat later in the day and may aid in arousal from daily torpor (Fenton and Barclay 1980). However, in our study the number of bats facing west did not differ significantly from random, and it does not appear that exposed roosts were selected in anticipation of the sun's evening position.

The high number of juveniles observed after early August is not in proportion to their occurrence within the population. *Myotis lucifugus* usually have one young per year (Fenton and Barclay 1980) and thus juveniles should occur in a 1:1 ratio with adult females. Juvenile little brown bats show less agility while flying than adults (Adams 1997), and their occurrence at exposed roosts may result from their inability to enter many enclosed roosts used by adults. Also, juveniles may not be aware of the locations of enclosed roosts used by adults, particularly during the fall migration period. In addition, following the breakup of maternal colonies in August, adult females disperse (Humphrey and Cope 1976; Schowalter et al. 1979), and may simply appear in lower numbers at exposed roosts as a result of having migrated to other areas.

The use of exposed roosts by *M. lucifugus* is probably opportunistic. Bats banded in other studies on exposed surfaces in Alberta were not recaptured at the same location (Schowalter et al. 1979; M.J. Pybus, unpublished data). In addition, removal of bats from buildings by property owners did not reduce the frequency of their occurrence there (Schowalter et al. 1979). In this study, bats were recorded using the same exposed site more than once only in cool weather and only on consecutive nights. These bats probably had not moved overnight.

Diurnal roosts used by little brown bats are usually enclosed (Fenton and Barclay 1980). However, the bats we observed in this study were relatively conspicuous and thus more vulnerable to predation or disturbance. The occurrence of this species at exposed locations in Alberta may reflect unspecified stresses not experienced by other populations. Since no population farther north has yet been studied, it is not known whether this behaviour is limited to Alberta populations or continues northward. Indeed, these stresses might be associated with decreased ambient temperatures in northern areas in late summer. Temperature may be the critical factor determining the use of exposed diurnal roosts in Alberta, as has been demonstrated in studying other survival strategies employed by this species in northern climates (Parker et al. 1997). However, the roosting ecology of *M. lucifugus* in northern climates demands further study.

Acknowledgments

The authors gratefully acknowledge the assistance of D.P. Hobson in field aspects of this study. Dr. Robert Barclay provided critical review and valuable suggestions for the manuscript. This study was funded by the Alberta Fish and Wildlife Division.

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An increase in habitat complexity reduces aggression and monopolization of food by zebra fish (*Danio rerio*)

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Abstract: We tested the predictions that an increase in the structural complexity of a habitat causes both a decrease in aggression and the monopolization of resources. Groups of three zebra fish (*Danio rerio*) were allowed to compete for food in a complex habitat with simulated vegetation and in a simple habitat with no vegetation. As predicted, both the levels of aggression by the dominant fish ($P = 0.050$) and the coefficient of variation of the amount of food eaten within a group ($P = 0.020$), a measure of food monopolization, were lower in the complex habitat than in the simple one. Fish that chased competitors more frequently ate more food in both habitats, but the relationship was stronger in the simple than in the complex habitat. Our results suggest that aggression is less useful as a mode of competition in habitats with greater structural complexity. Manipulating the structural complexity of the habitat may be a practical way of controlling the intensity of aggression and resource monopolization in groups of animals.

Résumé : Nous avons éprouvé les hypothèses selon lesquelles une augmentation de la complexité structurale d'un habitat peut entraîner à la fois une diminution de l'agressivité et une réduction de la monopolisation des ressources. Des groupes de trois poissons-zèbres (*Danio rerio*) ont été mis en présence de nourriture dans un habitat complexe avec de la végétation simulée, ou dans un habitat simple sans végétation. Tel que prévu, et l'agressivité des poissons dominants ($P = 0{,}050$) et le coefficient de variation de la nourriture mangée au sein d'un groupe ($P = 0{,}020$), une mesure de la monopolisation de la nourriture, étaient plus faibles dans le milieu complexe que dans le milieu simple. Les poissons qui poursuivaient les compétiteurs plus souvent ont mangé plus de nourriture dans les deux milieux, mais la relation était plus robuste dans l'habitat simple que dans l'habitat complexe. Nos résultats indiquent que l'agressivité est moins utile comme mode de compétition dans les habitats de structure plus complexe. La manipulation de la complexité structurale d'un habitat peut s'avérer une méthode pratique de contrôle de l'intensité de l'agressivité et de la monopolisation des ressources chez des groupes d'animaux.
[Traduit par la Rédaction]

Introduction

The ability of an animal to defend and monopolize resources is thought to be partly related to the structural complexity of its habitat. Increases in habitat complexity may increase the costs of defence by making it more difficult to detect and expel intruders from a territory (Schoener 1987; Eason and Stamps 1992). Intruders that are not immediately expelled consume food on the territory and reduce the growth rate of the territory owner (e.g., Stamps 1984; Stamps and Eason 1989). In addition, the longer an intruder remains on a territory, the more difficult it is to evict from the territory (Krebs 1982). Consequently, an increase in the structural complexity of a habitat is predicted to decrease territory size or the time allocated to patrolling and aggression (Schoener 1987).

Habitat complexity may also affect the monopolization of resources, the primary benefit of aggression. The foraging efficiency of fishes typically declines as the complexity of the

Received June 25, 1997. Accepted October 21, 1997.

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