RELATIONSHIP OF ORIENTATION ON INTERNAL TEMPERATURE OF ARTIFICIAL BAT ROOSTS, SOUTHWESTERN MONTANA

Jessie M. Peck, Department of Biology, Montana Tech, Butte, MT 59701[1]
Amy J. Kuenzi, Department of Biology, Montana Tech, Butte, MT 59701[2]

ABSTRACT

This study experimentally investigated if bat houses, built using a basic design, would provide suitable temperatures for roosting bats in southwestern Montana. Specifically, we looked at the effects of orientation (east vs. south) on the internal roost temperature, which was then compared to published data on the physiological temperature required for bat maternity roosting sites. We observed no use of the artificial roosting sites. There was a trend for southern-oriented bat houses to have slightly higher daily temperatures and slightly higher maximum temperatures. We determined that the internal temperature of the roosts did not remain in the optimum range for maternity roosts during most days and months. Most temperature readings were well below the minimum value. Bat houses built using a basic design do not appear to provide suitable temperature requirements for reproductive female bats in southwestern Montana. The information gathered by this study will allow us to continue to develop recommendations for design and placement of bat houses in southwestern Montana.

Key words: bats, bat houses, artificial roost sites, temperature requirements.

INTRODUCTION

In recent years there has been a growing public interest in bats and bat conservation (Fenton 1997). Bats have low reproductive rates and specific roost requirements, making them particularly vulnerable to environmental change (Hill and Smith 1984). Large population declines in some bat species have been documented (Humphrey 1978, Tuttle 1979, and Richter et. al 1993). Providing artificial roosting sites, e.g., bat houses, is often recommended to help offset the loss of natural roosts and aid in bat conservation (Brittingham and Williams 2000). Bat houses are readily available commercially or can be constructed using published plans (Tuttle 1988, and Tuttle and Hensley 1993). However, putting up a bat house does not guarantee its use by bats. Numerous factors including house design, size, exposure to sunlight and habitat influence whether or not a bat house will be inhabited (Tuttle and Hensley 1993). Most of these factors influence the house's internal temperature, one of the most important factors affecting roost suitability (Williams and Brittingham 1997).

However, data on actual roost temperature requirements for bats is limited. Licht and Lietner (1967) found that individuals of three species of California bats began to move to cooler parts of the roost when temperatures approached 40 °C. Big brown bats (*Eptesicus fuscus*) left their maternity roost site when temperatures exceeded 33-35 °C (Davis et al. 1968). But little brown bats (*Myotis lucifugus*) have been found in maternity roost sites with temperatures up to 55 °C (Davis et al. 1965, Henshaw and Folk 1966). Tuttle (1988) lists the optimum temperatures for nursery colonies of larger bats such as big brown bats at 27-32 °C , with the range for smaller *Myotis* spp. being 32-43 °C.

The effects of several bat house designs and placement on internal roost

---

[1] Current address: 724 S. 16th Ave., Bozeman, MT, 59715

[2] Contact for those ordering reprints

temperature have been tested in the eastern United States (Brittingham and Williams 2000). Little work however, has been done in the western United States and virtually none in the northern Rocky Mountain states (Kiser and Kiser 1999).

Our specific objectives were to provide artificial roosting sites for bats at 3 different sites in southwestern Montana, determine which species and number of bats using these bat houses, test effects of two different placement orientations (east-facing vs. south-facing) on internal temperatures of the houses, and compare internal temperatures in our houses with optimum temperatures for nursery colonies (Tuttle 1988).

METHODS

Bat House Construction and Placement

We constructed 14 bat houses using the "small economy bat house" plans of Tuttle and Hensley (1993). The dimensions of these houses were 67.3 cm X 60.9 cm X 6.4 cm (26.5" X 24" X 2.5"). All houses were painted black as recommended by Tuttle and Hensley (1993). We did not place a 1.27-cm (0.5-in) vent space in the front of the house because the plans indicated this may not be necessary in colder climates.

At the end of May 2001, we placed bat houses arranged in pairs at three sites in western Montana where foraging big brown bats and little brown bats are known to be present based on mist-net captures (Kuenzi, unpublished data). One house in each pair was oriented facing the south, the other facing east. We choose these two placements because bat houses oriented in a direction that has the maximum exposure to sunlight is recommended in cooler climates (Tuttle and Hensley 1993).

At the first site, Blacktail Creek walkway in Butte, Silver Bow County, we placed two pairs of bat houses in cottonwood trees along the creek. At the second site, Warm Springs Wildlife Management Area, Deer Lodge County, we placed three pairs of bat houses in cottonwood trees (*Populus* spp.) located along a large irrigation canal that contains water year round. At the final site, the Mount Hagan Wildlife Management Area, Deer Lodge County, we placed three pairs of bat houses on abandoned buildings located within 20 m of a small creek. Elevation at the three sites were as follows: 1554 m at Blacktail Creek; 1467 m at Warm Springs; and 1914 m at Mount Hagan. We visually checked all bat houses for the presence of bats approximately every 3 weeks from June through September 2001 and from April through July 2002.

Temperature Data

Temperature data were collected from 14 June through 30 September 2001, and from 1 April through 19 May 2002 using four Hobo temperature data loggers (Onset Computer Corporation, Bourne MA). Data loggers were placed inside two pairs of houses/site and were programmed to collect temperature data on an hourly basis. Data loggers remained at a site for at least 2 weeks before being moved to another site.

We averaged temperatures daily within each placement orientation (south, east) at a site. We also determined daily minimum and maximum temperatures for each orientation. Daily averages as well as daily minimum and maximum temperatures were then averaged within each month at a site.

We used paired *t*-tests (Sokal and Rohlf 1995) to determine if internal house temperatures differed with placement orientation. Paired t-tests were done for each site and time of data collection.

We performed all statistical analyses using JMP (SAS Institute 1996). Alpha of 0.05 was used in all statistical tests, and data are presented as $\bar{x} \pm 1$ standard error unless indicated otherwise.

To determine how the temperatures in our bat houses differed from the optimum range for big brown and little brown bat maternity colonies, we calculated the percentage of temperature readings that was less than the minimum range value, the percentage of readings that was above the maximum value, and the percentage of temperature readings that were within the range. We calculated these values at each site and recorded the time of data collection.

RESULTS

We did not document any use of bat houses by bats during the course of this study. Internal temperatures in bat houses were highly variable on a daily basis with difference between minimum and maximum temperatures ranging from ~13 °C in April up to 30 °C in August (Table 1). We observed a trend for southern-oriented bat houses to have slightly higher daily temperatures and slightly higher maximum temperatures. However, the results of paired *t*-test comparisons show that southern-oriented bat houses had significantly higher temperatures in only 5 of 14 (35.7%) comparisons that we made (Table 2). In most cases there was no difference between temperatures in south versus east oriented houses and in July at the Blacktail Creek site, houses that faced east had significantly higher temperatures than the south-facing houses.

A high percentage of each month's temperature readings were below the optimal temperature range for both big brown bats and little brown bats (Table 3). The percentage of temperature readings within the optimal range for big brown bats varied from 0 in all houses during April up to ~35 percent for a south-facing house in September (Table 3). In general houses that faced east had a higher percentage of readings within the optimal range for this species. The percentage of monthly temperature readings within the optimal range for little brown bats was much lower ranging from 0 to 14.5 percent (Table 3). In general houses that faced south had a slightly higher percentage of readings within the optimal range.

DISCUSSION

Big brown bats and little brown bats commonly forage in and around our three study sites (Kuenzi, unpublished data). Both species are known to use artificial roost sites (Williams and Brittingham 1997, Neilson and Fenton 1994) and both form maternity colonies usually by mid-May (Davis et al. 1968, Barbour and Davis 1969, Fenton and Barclay 1980, Kurta and Baker 1990). However, it has been suggested that in more northern regions maternity colonies may form somewhat later (Fenton and Barclay 1980). The amount of precipitation in the spring may also influence the exact timing of maternity colony formation (Grindal et al. 1992).

Temperatures in our bat houses were often below the optimal range for maternity colonies of both big brown bats and little brown bats. Granted that each day varied somewhat in temperature, but overall our artificial roosts did not remain in the range of optimal temperatures for more than an hour or two at a time. We doubt that maintaining suitable internal temperatures for such short periods would provide a viable environment for female bats with young.

Roost temperature at maternity sites has a strong influence on reproductive success. When ambient temperature is low many bat species can optimize energy and water savings by entering torpor, a reduction in body temperature. Although male bats regularly use torpor during spring and summer (Grinevitch et al. 1995), pregnant females who enter torpor delay parturition, which could leave their offspring with too short a season to acquire fat stores needed for winter survival (Rydell 1989). Therefore reproductively active females select roost sites that allow them to minimize their use of torpor and maximize growth rates of their young (Audet and Fenton 1988). In addition, very young bats do not thermoregulate, thus roost temperature is very important to their survival (Kunz 1987).

The main problem with our bat houses as suitable sites for reproductive females was low internal temperature; thus, greater exposure to sunlight may raise the internal roost temperature sufficiently. Bat houses at Warm Springs and Blacktail Creek were partially shaded by trees at least part of the day, therefore, mounting the houses in the open on poles would allow greater exposure

Table 1. Average daily temperature and average daily minimum and maximum temperatures ($\bar{x}$ ± 1 SE) inside bat houses by month at sites in southwestern Montana.

Month	Site	Orientation of bat house	Ave. daily temp.	Ave. daily maximum temp.	Ave. daily minimum temp.	Number of days
April	Warm Springs	South	6.2 ± 0.7	17.1 ± 0.9	-4.1 ± 0.7	30
		East	5.3 ± 0.7	16.5 ± 1.0	-3.2 ± 0.7	30
May	Warm Springs	South	10.3 ± 1.0	21.6 ± 1.5	-0.2 ± 0.8	22
		East	9.2 ± 0.9	19.9 ± 1.4	0.7 ± 0.7	22
June	Mt. Hagan	South	14.3 ± 1.2	31.1 ± 2.0	3.2 ± 1.1	19
		East	14.2 ± 1.3	29.2 ± 1.8	1.8 ± 1.1	19
July	Mt. Hagan	South	17.6 ± 0.9	32.5 ± 2.0	7.2 ± 0.7	17
		East	17.6 ± 0.9	34.0 ± 1.5	5.6 ± 0.7	17
July	Blacktail Creek	South	16.8 ± 0.7	28.0 ± 0.9	8.2 ± 0.3	14
		East	18.2 ± 0.8	34.9 ± 1.4	8.3 ± 0.4	14
August	Warm Springs	South	21.3 ± 0.3	40.4 ± 0.7	6.9 ± 0.6	31
		East	20.2 ± 0.3	34.4 ± 0.5	7.4 ± 0.5	31
September	Warm Springs	South	20.3 ± 0.3	36.9 ± 1.9	5.8 ± 1.7	4
		East	19.7 ± 0.3	36.0 ± 0.8	5.9 ± 1.8	4
September	Mt. Hagan	South	13.5 ± 0.5	35.9 ± 1.3	-0.1 ± 0.7	26
		East	13.3 ± 0.6	32.9 ± 1.4	-0.7 ± 0.7	26

to sunlight. However, bat houses at Mount Hagan were not shaded by trees and their internal temperatures remained low. In addition to increasing exposure to sunlight, mounting bat houses on poles has been recommended as a way to provide protection from mammalian predators (Tuttle and Hensley 1997). Insulating the houses might help to provide a higher and more stable internal temperature. Others have suggested that mounting houses directly on the side of occupied buildings also provides some degree of insulation (Tuttle and Hensley 1993).

Although this study did not find an internal roost temperature that was overly high to be a problem, as measures are taken to raise the internal roost temperature, this may become an issue. Williams and Brittingham (1997) found if the microclimate of one part of the bat house was too high, bats would move to a part of the bat house that had a cooler microclimate rather than abandoning the roost. Plans for

Table 2. Results of paired *t*-tests comparing internal temperatures of south versus east facing bat houses at three sites in southwestern Montana.

Month	Site	House pair number	*t*-value	*P*-value	Direction with higher temperature
April	Warm Springs	1	6.17	< 0.001	South
May	Warm Springs	1	7.32	< 0.001	South
June	Mt. Hagan	1	0.15	0.884	No difference
		2	-1.09	0.275	No difference
July	Mt. Hagan	1	-0.07	0.942	No difference
		2	-0.17	0.860	No difference
July	Blacktail	1	-5.87	< 0.001	East
		2	-8.79	< 0.001	East
August	Warm Springs	1	5.62	< 0.001	South
		2	5.82	< 0.001	South
September	Warm Springs	1	1.64	0.104	No difference
		2	0.54	0.590	No difference
September	Mt. Hagan	1	4.01	< 0.001	South
		2	-1.47	< 0.140	No difference

Table 3. Percentage of hourly temperature readings from bat houses in southwestern Montana that were below the minimum temperature value, above the maximum temperature value, and were in the range of temperature values for maternity roosting sites. Sample sizes are shown in parentheses.

Month	Site	Orientation of bat house	Pair	Percentage of readings below 27 °C	Percentage of readings above 32 °C	Percentage of readings between 27- 32 °C[1]	Percentage of readings between 32- 43 °C[2]	Percentage of readings above 43 °C
April	Warm Springs	South	1	100 (720/720)	0	0	0	0
		East		100 (720/720)	0	0	0	0
May	Warm Springs	South	1	95.4 (496/520)	0.2 (1/520)	4.4 (23/520)	0.2 (1/520)	0
		East		97.3 (506/520)	0.0	2.7 (14/520)	0	0
June	Mt. Hagan	South	1	85.2 (379/445)	7.4 (33/445)	7.4 (33/445)	7.2 (32/445)	0.2 (1/445)
		East		83.1 (370/445)	6.3 (28/445)	10.6 (47/445)	6.3 (28/445)	0
		South	2	88.3 (391/443)	6.1 (27/443)	5.6 (25/443)	6.1 (27/443)	0
		East		87.1 (386/443)	1.1 (5/443)	11.8 (52/443)	1.1 (5/443)	0
July	Mt. Hagan	South	1	82.0 (323/394)	8.9 (35/394)	9.1 (36/394)	8.6 (34/394)	0.3 (1/394)
		East		76.4 (301/394)	12.4 (49/394)	11.2 (44/394)	12.4 (49/394)	0
		South	2	81.5 (322/395)	7.6 (30/395)	10.9 (43/395)	7.1 (28/395)	0.5 (2/394)
		East		77.2 (305/395)	5.8 (23/395)	17.0 (67/395)	5.8 (23/395)	0
July	Blacktail Cr.	South	1	89.5 (280/313)	0.6 (2/313)	9.9 (31/313)	0.6 (2/313)	0
		East		75.1 (235/313)	10.5 (33/313)	14.4 (45/313)	10.5 (33/313)	0
July	Blacktail Cr.	South	2	94.9 (298/314)	0.3 (1/314)	4.8 (15/314)	0.3 (1/314)	0
		East		91.4 (287/314)	0	8.6 (27/314)	0	0
August	Warm Springs	South	1	73.8 (549/744)	14.1 (105/744)	12.1 (90/744)	12.5 (93/744)	1.6 (12/744)
		East		81.9 (609/744)	1.7 (13/744)	16.4 (122/744)	1.7 (13/744)	0
		South	2	61.2 (455/744)	11.8 (88/744)	27.0 (201/744)	11.6 (86/744)	0.3 (2/744)
		East		69.6 (518/744)	11.6 (86/744)	18.8 (140/744)	11.6 (86/744)	0
September	Warm Springs	South	1	73.3 (66/90)	14.5 (13/90)	12.2 (11/90)	14.5 (13/90)	0
		East		73.3 (66/90)	0	26.7 (24/90)	0	0
		South	2	60.7 (54/89)	4.5 (4/89)	34.8 (31/89)	4.5 (4/89)	0
		East		66.3 (59/89)	12.4 (11/89)	21.3 (19/89)	12.4 (11/89)	0
September	Mt. Hagan	South	1	85.3 (521/611)	8.8 (54/611)	5.9 (36/611)	8.3 (51/611)	0.5 (3/611)
		East		81.0 (495/611)	9.2 (56/611)	9.8 (60/611)	9.2 (56/611)	0
		South	2	82.8 (505/610)	9.3 (57/610)	7.9 (48/610)	8.5 (52/610)	0.8 (5/610)
		East		82.3 (502/610)	8.2 (50/610)	9.5 (58/610)	8.2 (50/610)	0

[1] These percentages represent the percentage of temperature readings in the optimal range for *E. fuscus*.

[2] These percentages represent the percentage of temperature readings in the optimal rang

the construction of bat houses with several internal chambers are available (Tuttle and Hensley 1993). Although these houses are more costly and difficult to construct they may provide a wider range of temperatures.

The temperatures provided by our roost sites were likely unsuitable, especially for reproductive females. The houses may provide suitable temperatures for male bats who can tolerate lower temperatures (Hamilton and Barclay 1994). However, we did not observe any bats using our houses. One explanation could be that bats have yet to discover the houses. Although occupancy in many successful houses occurs during the first summer season of placement, occupation of houses by bats sometimes takes several seasons (Tuttle and Hensley 1993). During the first summer of our study our bat houses may have been put up too late in the season (end of May). Although maternity colonies are forming at this time, individuals were likely looking for roosting sites earlier in the season. A final reason for the non-use of the houses in this study may be that suitable natural roosting sites are not limited in the study areas.

We plan to continue this study in several different ways, the first is to leave up the present houses and monitor them for another year or two. Next we plan on examining the temperatures and use of different house designs, such as multiple-chambered houses. We also plan to examine the effects of factors such as insulation and placing houses in a southeast orientation on internal temperature and occupancy rates.

ACKNOWLEDGEMENTS

We thank R. Douglass, K. Douglass, M. Cerise, S. Nyland, D. Tziakek, and K. Ball for their assistance. Funding for this study was provided by the Montana Tech Undergraduate Research Program and the Montana Audubon Society. Additional funding was provided by Brandon Legg Construction and Ace Hardware in the form of supplies for bat house construction.

LITERATURE CITED

Audet, D., and M. B. Fenton. 1988. Heterothermy and the use of torpor by the bat *Eptesicus fuscus*: a field study. Physiological Zoology 61:197-204.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. University of Kentucky Press, Lexington.

Brittingham, M. C., and L. M. Williams. 2000. Bat boxes as alternative roosts for displaced bat maternity colonies. Wildlife Society Bulletin 28:197-207.

Davis, W. H., M. D. Hassell, and M. J. Harvey. 1965. Maternity colonies of the bat *Myotis I. lucifugus* in Kentucky. American Midland Naturalist 73:161-165.

_____, R. W. Barbour, and M. D. Hassell. 1968. Colonial behavior of *Eptesicus fuscus*. Journal of Mammalogy 49:44-50.

Fenton, M. B. 1997. Science and the conservation of bats. Journal of Mammalogy 78:1-14.

_____, and Barclay, R.M.R. 1980. *Myotis lucifugus*. Mammalian Species 142:1-18.

Grindal, S.D., Collard, T.S., Brigham, R.M., Barclay, R.M.R. 1992. The influence of precipitation on reproduction by *Myotis* bats in British Columbia. American Midland Naturalist 128:339-346.

Grinevitch, L., S. L. Holroyd, and R. M. R. Barclay. 1995. Sex differences in the use of daily torpor and foraging time by big brown bats (*Eptesicus fuscus*) during the reproductive season. Journal of Zoology 235:301-309.

Hamilton, I. M. and R. M. R. Barclay. 1994. Patterns of daily torpor and day-roost northern bat *Eptesicus nilssoni* during pregnancy and lactation. Oecologia 80:562-565.

SAS Institute Inc. 1996. JMP start statistics. A guide to statistics and data analysis using JMP and JMP IN software. Wadsworth Publishing Company, Belmont, CA.

selection by male and female big brown bats (*Eptesicus fuscus*). Canadian Journal of Zoology 72:744-749.

Henshaw, R. E., and G. E. Folk. Jr. 1966. Relation of theromoregulation to seasonally changing microclimate in two species of bat (*Myotis lucifugus* and *Myotis sodalis*). Physiological Zoology 39:223-236.

Hill, J. E., and J. D. Smith. 1984. Bats: a natural history. University of Texas Press, Austin.

Humphrey, S. R. 1978. Status, winter habitat, and management of the endangered Indiana bat (*Myotis sodalis*). Florida Scientist 41:65-76.

Kiser M., and S. Kiser. 1999. Experiments Needed. Bat House Researcher 7:6.

Kunz, T. H. 1987. Post-natal growth and energetics of suckling bats. Pp. 395-420 *in* M. B. Fenton, P.A. Racey, and J. M. V. Rayner, eds. Recent advances in the study of bats. Cambridge University Press, Cambridge, UK.

Kurta, A., and R. H. Baker. 1990. *Eptesicus Fuscus*. Mammalian Species 356:1-10.

Licht, P., and P. Leitner. 1967. Behavioral responses to high temperatures in three species of California bats. Journal of Mammalogy 48:52-61.

Nielson, A. L., and M. B. Fenton. 1994. Response of little brown *Myotis* to exclusion and to bat houses. Wildlife Society Bulletin 22:8-14.

Received 29 January 2003
Accepted 17 April 2003

Richter, A. R., S. R. Humphrey, J. B. Cope, and V. Brack, Jr. 1993. Modified cave entrances: thermal effect on body mass and resulting decline of endangered Indiana bats (*Myotis sodalis*). Journal of Conservation Biology 7:407-415.

Rydell, J. 1989. Feeding activity of the northern bat *Eptesicus nilssoni* during pregnancy and lactation. Oecologia 80:562-565.

SAS Institute Inc. 1996. JMP start statistics. A guide to statistics and data analysis using JMP and JMP IN software. Wadsworth Publishing Company, Belmont, CA.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry. 3rd Edition. W. H. Freeman, San Francisco, CA.

Tuttle, M. D. 1979. Status, causes of decline, and management of endangered graybats. Journal of Wildlife Management 45:1-17.

_____. 1988. America's Neighborhood Bats. University of Texas Press, Austin.

_____, and D. L. Hensley. 1993. The bat house builder's handbook. Bat Conservation International, Austin, TX.

Williams, L. M., and M. C. Brittingham. 1997. Selection of maternity roosts by big brown bats. Journal of Wildlife Management 61:359-368.