

# BODY TEMPERATURE AND AROUSAL RATES OF TWO SPECIES OF BATS<sup>1, 2</sup>

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## ABSTRACT

Body temperature during torpidity and arousal were recorded on single and grouped *Myotis lucifugus* and *M. sodalis* maintained at 6° in the laboratory. The two species possess physiological differences in their temperature regulatory capacities in response to clustering behavior.

The temperate-zone Chiroptera have the ability to undergo cold lethargy seasonally and in some cases also daily throughout the summer. Eisentraut (1960) classified bats as the most imperfect mammalian thermoregulators while Stones and Weibers (1965) indicated that all species of Chiroptera have some degree of thermal regulation although the complexity of its nature and mechanism is still unknown. Hence, species vary in their capacity to maintain a constant body temperature. Complete endothermy is found in the vampire, *Desmodus rotundus* (Wimsatt, 1962; Lyman and Wimsatt, 1966), seasonal diurnal torpidity in *Eumops perotis* (Leitner, 1962), and daily torpidity in the cave bat, *Myotis velifer* (Twente, 1955). Some species which inhabit a hot dry climate exhibit a type of "Hemipoikothermy" (Reeder and Cowles, 1951). Studier and Wilson (1970) found the eleven species of neotropical bats exhibited torpidity and recovery upon warming. Herreid (1963) states that *Tadarida mexicana* maintains a non-torpid body temperature during the day only when in groups and is subject to disturbances from other individuals. Henshaw (1970) indicated that the physiological regulatory capacities correlated with, and probably determined, the microclimates that bats select for hibernation.

Behavior may be an important aspect in thermoregulation in bats. Licht and Leitner (1967) indicated the importance of behavior in the thermoregulation of three species of bats subjected to high environmental temperatures. Henshaw (1972) stated that social behavior during hibernation appears to be related to individual species differences not latitude. Vespertilionids may be nearly evenly divided among solitary, seasonally colonial, and year around colonial social habits. However, all of the 13 species of *Myotis* are colonial either year round or seasonally. The clustering of *Myotis sodalis* and *M. lucifugus* has been suggested as a behavioral adaptation related to the physiology of the species during hibernation (Hall, 1962; Henshaw, 1965 and Henshaw and Folk, 1966; Henshaw, 1972). *Myotis lucifugus* hibernates in groups of 10 to several hundred, whereas, *M. sodalis* hibernates in groups of 1,000 or more individuals. The present study investigated the differences in body temperature during torpidity and arousal of single and grouped individuals to determine if behavior was related to thermoregulation in these two species.

## METHODS

The bats utilized in this study were obtained from two hibernating colonies in Pennsylvania: *Myotis lucifugus* from Laurel Caverns near Uniontown and *M. sodalis* from an abandoned cement mine near Altoona, Pennsylvania. Both species were transported to the laboratory within 5 hours of their removal from the hibernating colonies. Upon arrival at the laboratory, the bats were placed into an hibernaculum maintained at 6° C with a relative humidity of 66%. These conditions compare favorably with the environmental temperature 6° C and 67% relative humidity recorded at the hibernating sites. Bats were housed singly or in groups and were acclimated to the hibernaculum for five days prior to the recording of body temperatures.

<sup>1</sup>Manuscript received March 7, 1973 (73-19).

<sup>2</sup>Supported by a Grant-in-Aid for research from the Society of the Sigma Xi.

A YSI telethermometer, Model 44TZ, was used to monitor all temperature. Flexible rectal probes were taped in place after being inserted 1-2 cm. Surface temperatures were recorded with a flat surface probe attached to body of the animal and intrascapular brown fat temperatures were recorded with a small needle implantation probe taped to the animal. Temperatures were only recorded on single and grouped bats which were in a torpid state, with an internal body temperature within  $\pm 1^{\circ}\text{C}$  of ambient.

Bats were allowed to acclimate for an hour following the initial temperature recordings. The body temperatures were then re-recorded to insure that arousal had not occurred due to the disturbances during recording. Single and paired bats were removed from the hibernaculum, and temperatures were recorded. Single bats and pairs were then placed in a 250 ml breaker at  $23.7^{\circ}\text{C}$  and their body temperatures were recorded during arousal (TA). Bats which were originally housed as single individuals were used to determine the body temperature during arousal of single bats, and those which were housed in groups were used to determine temperature changes during arousal of paired individuals. Temperatures were recorded at five minute intervals for 30 minutes during arousal (fig. 1). In order to determine the exogenous heat load from the environment, simultaneous measurements were recorded on dead individuals.

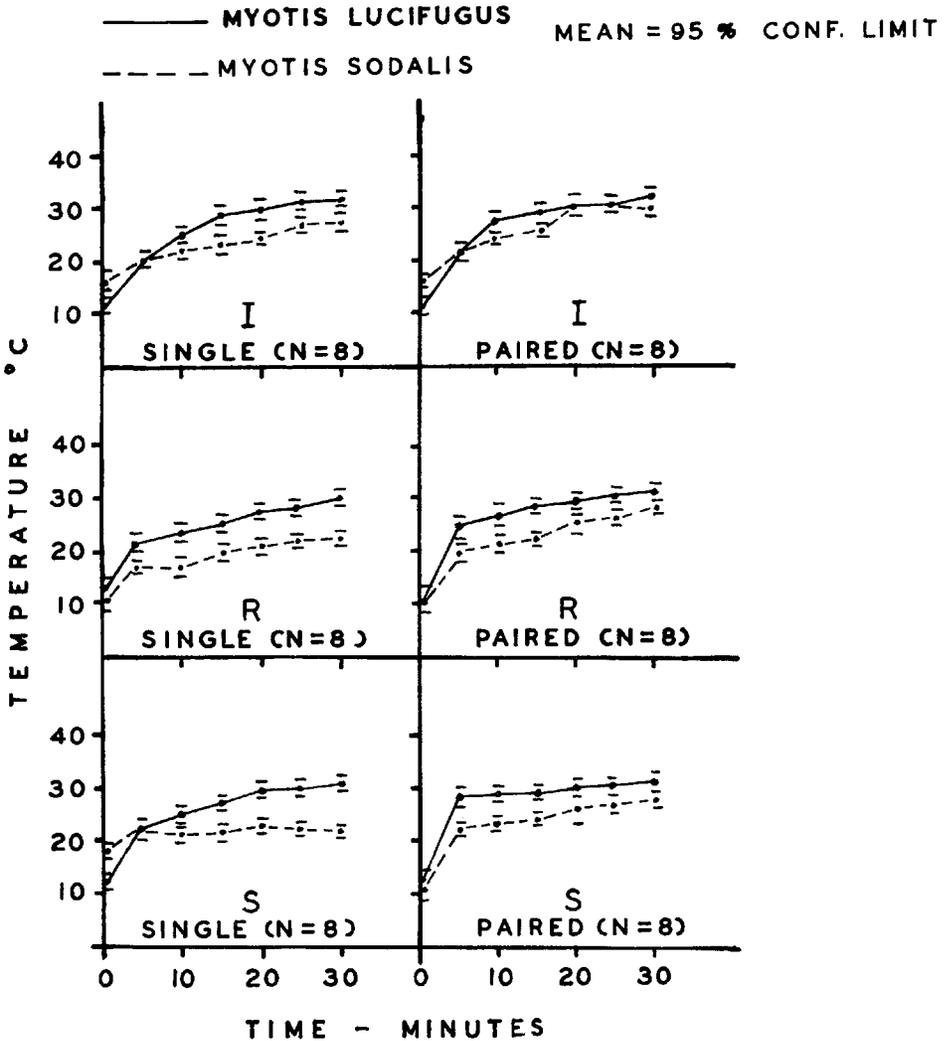


FIGURE 1. The change in three body temperature during arousal in *Myotis lucifugus* and *M. sodalis* (I—intrascapular; R—rectal; and S—surface).

## RESULTS

The representatives of the two species maintained in the laboratory followed a behavior pattern similar to that which had been observed in natural hibernating colonies. A group of 24 *Myotis sodalis* formed a tight cluster at the back of the cage, whereas, *M. lucifugus* roosted in a small group of 5 to 10 individuals in different areas of the cage. A difference did occur in the internal ( $T_R$ ) rectal body temperatures between grouped and single individuals of both species. Single *M. lucifugus* had a lower  $\Delta T$  between  $T_A$  and  $T_R$  than did grouped individuals, and the reverse occurred between grouped and single *M. sodalis*. However, the difference was not significant at the  $P < .05$  level in either case. Similarly, the  $\Delta T$  between  $T_I$  (the intrascapular temperature) and  $T_A$  was less in grouped *M. sodalis* than it was in single individuals ( $P < .1$ ), but no difference in these temperatures occurred in *M. lucifugus* (table 1). Even though these differences are not mathematically significant they may be important in the survival of the species.

TABLE 1  
The  $\Delta T$  between the environmental temperature of 6° C and the three body temperatures of *Myotis lucifugus* and *Myotis sodalis*

| Species                 | Number | Surface<br>$\Delta T$ | Rectal<br>$\Delta T$ | Brown<br>Adipose<br>$\Delta T$ |
|-------------------------|--------|-----------------------|----------------------|--------------------------------|
| <i>Myotis lucifugus</i> |        |                       |                      |                                |
| Single                  | 8      | 1.4 ± .073            | 5.0 ± 0.80           | 4.7 ± 0.27                     |
| Grouped                 | 8      | 1.7 ± .017            | 7.0 ± 0.28           | 4.5 ± 0.22                     |
| <i>Myotis sodalis</i>   |        |                       |                      |                                |
| Single                  | 8      | 1.7 ± .070            | 7.0 ± 0.82           | 8.9 ± 0.74                     |
| Grouped                 | 8      | 1.5 ± .019            | 5.5 ± 0.17           | 6.9 ± 0.47                     |

The two species exhibited different  $\Delta T$  between the various temperatures. The  $\Delta T$  between the rectal  $T_R$  and  $T_S$  (the surface temperature) of 2.7° C was significantly less in single than in grouped *M. lucifugus*. Likewise, a significant  $\Delta T$  of 2.2° C occurred in single *M. lucifugus* compared with grouped animals. However, no significant difference occurred between the  $\Delta T$  or between  $T_I$  and  $T_S$  of grouped and single *M. lucifugus*. There was no significant difference in the  $\Delta T$  for the temperatures of single and grouped *M. sodalis*. However, a significant difference did occur between the two species in both single and grouped individuals. The  $\Delta T$  of 3.6° between the  $T_R$  and  $T_S$  in single *M. lucifugus* was significantly less than the  $\Delta T$  5.3° which occurred in single *M. sodalis* ( $P < .05$ ). The reverse occurred in grouped individuals where the  $\Delta T$ 's were +6.3° and +5.0° or grouped *M. lucifugus* and *M. sodalis*, respectively. The  $\Delta T$  between the  $T_I$  and  $T_R$  also varied significantly between the two species. The  $\Delta T$  of -0.3° in single *M. lucifugus* was significantly different than the  $\Delta T$  of +1.9° which occurred in *M. sodalis*, ( $P < .01$ ). Likewise, the  $\Delta T$  of -2.5° C which occurred in grouped *M. lucifugus* was significantly different than the +1.4° C  $\Delta T$  in grouped *M. sodalis*. Grouped and single *M. sodalis* maintained a significantly greater  $\Delta T$  between  $T_S$  and  $T_I$  temperature than did *M. lucifugus* ( $P < .001$ ) (table 2). These differences in  $\Delta T$  for various temperatures suggests that physiological differences and/or behavior during hibernation influence their thermoregulatory capacities.

No difference existed between single or grouped bats of either species in ability to arouse from torpor. A similar rate of change occurred in the three temperatures for the two species ( $P > .50$ ) and between grouped and single individuals of the same species ( $P > .50$ ). Concerning exogenous heat load from the environment

it was noted that the average increase in  $T_R$  of a dead bat was 4.5° C over the 30 minute period. Hence, the exogenous heat load accounted for 22.5% of the increase in *M. lucifugus*, but only 16.5% in *M. sodalis*. Therefore, the exogenous heat load produced by the animals varied from 77.5% to 83.5% of the total rise in  $T_R$  heat production in these species.

TABLE 2  
The  $\Delta T$  between the various body temperatures in two species of bats maintained at 6° C

| Species                 | Rectal-Surface<br>$\Delta T$ | Brown Adipose-<br>Rectal<br>$\Delta T$ | Brown Adipose-<br>Surface<br>$\Delta T$ |
|-------------------------|------------------------------|--|---|
| <i>Myotis lucifugus</i> |                              |  |   |
| Single                  | +3.6±0.24                    | -0.3±0.03                              | +3.3±0.15                               |
| Grouped                 | +6.3±0.19                    | -2.5±0.18                              | +2.8±0.13                               |
| <i>Myotis sodalis</i>   |                              |  |   |
| Single                  | +5.3±0.24                    | +1.9±0.32                              | +7.2±0.23                               |
| Grouped                 | +5.0±0.11                    | +1.4±0.21                              | +5.4±0.18                               |

It was observed that *M. sodalis* was capable of movement at lower temperatures than *M. lucifugus*. Grouped *M. sodalis* also became active at a lower body temperature than did single individuals of the same species. Therefore, *M. sodalis* may possess a lower temperature threshold for activity than does *M. lucifugus*, and grouping behavior may result in a mutual stimulation of individuals within the group.

#### DISCUSSION

Studies on natural hibernating populations of *M. lucifugus* and *M. sodalis* have suggested that a difference in behavior and temperature preferences exists among the two species. *M. sodalis* selected temperatures between 9° and 10° in the fall and between 4° and 6° at mid-winter, while *M. lucifugus* have been observed hibernating at temperatures between 1°-13° (Hall, 1962; Henshaw, 1965). Comparison of the thermoregulatory capacities of these two species has been adequately reviewed by Henshaw (1970). Henshaw (1965) and Henshaw and Polk (1966a, b) found that *M. lucifugus* exhibits a deeper torpor than *M. sodalis*. It was observed in this study that *M. sodalis* was capable of becoming active at lower body temperatures than was *M. lucifugus*, suggesting a shallower torpor exists in *M. sodalis*.

Hanus (1959) stated that bats were capable of increasing their body temperature from 15° to approximately 36° in about 15 minutes without any visible signs of movement except slight muscular tremors when the body temperature had risen to between 20 to 30. The muscular movement by *M. sodalis* at lower body temperatures than *M. lucifugus* could serve as an arousal stimulus for other bats within the cluster. During the early stages of arousal, neural stimulation may be an important factor, but muscular activity becomes important during the latter phases of arousal.

The anatomical distribution and thermogenic responses of brown adipose tissue have led several investigators to suggest that it may have an important function in thermogenesis in hibernating animals (Smith and Hock, 1963; Smith, 1964; and Smalley and Dryer, 1963, 1967). Smalley and Dryer (1963) stated that in *Eptesicus fuscus* the temperature of the brown fat exceeded that of other tissues by about 3° during the late stages of arousal. Studier (1974) found that the chest muscles warm slightly faster than rectal temperatures during arousal in *Eptesicus*

*fuscus* and *Myotis sodalis*. The difference in the  $\Delta T$  between rectal  $T_R$  and Intra-scapular  $T_I$  temperatures observed during this study suggest that the subscapular region may have an important function in thermoregulation in *M. lucifugus* and *M. sodalis*.

Clustering behavior of both species probably aids in thermoregulation and also in aspects of survival during hibernation. Brenner (1973) found that *M. sodalis* utilizes body tissues with less water loss during torpor than does *M. lucifugus*, indicating a difference in the energy and water requirements of the two species during torpor. Henshaw (1970) indicated that clustering behavior may create a more favorable microclimate for hibernation, thereby reducing the amount of physiological compensation required by the individuals. The degree of clustering among the various species may be in part due to the thermoregulatory capacities and other physiological functions of the different species.

#### LITERATURE CITED

- Brenner, F. J. 1973. Influence of daily arousal on body composition of two species of *Myotis* (Mammalia: Chiroptera). Proc. Pa. Acad. Sci. 47: 77-78.
- Eisentraut, M. 1960. Heat regulation in primitive mammals in tropical species. P. 24-43. In C. P. Lyman and R. A. Dawe. Eds. Mammalian Hibernation. Bull. Mus. Comp. Zool. 124: 1-549.
- Hall, J. S. 1962. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Reading Public Museum and Art Gallery, Reading, Pa. Publ. No. 12.
- Hanus, K. 1959. Body temperature and metabolism in bats at different environmental temperatures. Physiol. Bohemoslov. 8: 230-259.
- Henshaw, R. E. 1965. Physiology of hibernation and acclimation in two species of bats (*Myotis lucifugus* and *Myotis sodalis*). Unpub. Ph.D. Thesis. State Univ. Iowa.
- 1970. Thermoregulation in bats. In About Bats. Eds.: Slaughter and Walton. Southern Methodist Univ. Press. Dallas. pp. 188-232.
- 1972. Niche specificity and adaptability in cave bats. Bull. Nat., Speleological Soc. 34: 61-70.
- Henshaw, R. E. and G. E. Folk, Jr. 1966a. Relation of thermoregulation to seasonally changing microclimate in two species of bats (*Myotis lucifugus* and *Myotis sodalis*). Physiol. Zool. 39: 223-236.
- 1966b. Thermal conductance, basal metabolic rate, and zone of thermal neutrality in hibernating bats. Fed. Proc. 25: 274.
- Herreid, C. F. 1963. Temperature regulation of Mexican free-tailed bats in cave habitats. J. Mammal. 44: 560-573.
- Leitner, P. 1962. Body temperature regulation in the California mastiff bat, *Eumops perotis*. Amer. Zool. 2: 535.
- Licht, P. and P. Leitner. 1967. Behavior response to high temperatures in three species of California bats. J. Mammal. 48: 52-61.
- Lyman, C. P. and W. A. Wimsatt. 1966. Temperature regulation in the vampire bat, *Desmodus rotundus*. Physiol. Zool. 39: 101-109.
- Reeder, W. G. and R. B. Cowles. 1951. Aspects of thermoregulation in bats. J. Mammal. 32: 389-403.
- Smalley, R. L. and R. L. Dryer. Brown fat: Thermogenic effect during arousal from hibernation in the bat. Science 140: 1333-1334.
- 1967. Brown fat in hibernation. In: Mammalian Hibernation III. Ed. Fisher et al. Am. Elsevier Pub. Co., Inc., New York. pp. 325-355.
- Smith, R. E. 1964. Thermoregulatory and adaptive behavior of brown adipose tissue. Science 146: 1686-1689.
- Smith, R. E. and R. J. Hock. 1963. Brown fat: Thermogenic effector of arousal in hibernators. Science 140: 199-200.
- Stones, R. C. and J. E. Weibers. 1965. A review of temperature regulation in bats (Chiroptera). Am. Midl. Nat. 74: 155-167.
- Studier, E. H. 1974. Differential in rectal and chest muscle temperature during arousal in *Eptesicus fuscus* and *Myotis sodalis* (Chiroptera: vespertilionidae). Comp. Biochem. Physiol. 47: 799-802.
- Studier, E. H. and D. E. Wilson. 1970. Thermoregulation in some neotropical bats. Comp. Biochem. Physiol. 34: 251-262.
- Twente, J. W. 1955. Aspects of a population study of cavern-dwelling bats. J. Mammal. 36: 379-390.
- Wimsatt, W. A. 1962. Responses of captive common vampire bat to cold and warm environments. J. Mammal. 43: 185-191.