THERMOREGULATORY BEHAVIOUR IN THE TOADS

BUFO MARINUS AND BUFO COGNATUS

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Abstract—1. The temperature preference of *Bufo marinus* in a linear thermal gradient over a 24 h period was measured in the spring using uniform light (UL) over the length of the gradient and in the spring and fall using a point source of light over the hot end of the gradient only (LH).
2. The temperature preference of *Bufo cognatus* in a linear thermal gradient was measured over a 24 h period during the fall with the LH regime.
3. Light regime and season had no effect on the mean body temperature (*Tb*) selected over a 24 h period in *Bufo marinus*. The pattern of temperature selection over time was influenced by season.
4. Temperate *Bufo cognatus* selected significantly higher mean *Tb* s than the tropical *Bufo marinus* and selected significantly higher *Tb* s during late photophase than late scotophase.

Key Word Index: Thermoregulation; *Bufo*; toad

INTRODUCTION

Behavioural thermoregulation in ectotherms, especially reptiles, has been widely studied (Brattstrom, 1965, 1979; Avery, 1982). Amphibians are faced with the same benefits of elevating body temperature (*Tb*) as reptiles. Such benefits include increased digestive rate, development, growth and appetite (Brattstrom, 1979; Lillywhite *et al.*, 1973; Duellman and Trueb, 1985). Yet, the cost of elevating *Tb* differs between the two groups because amphibians are more prone to dehydration. At high *Tb* s more heat is lost through cutaneous water loss. *Bufo spinosus* lost considerably more mass, presumably due to dehydration, than the lizard *Liolaemus multiforis* during basking (Pearson and Bradford, 1976). Therefore, only those amphibians with a reliable source of water can allow *Tb* to rise for any length of time. Despite this problem anurans do bask in the sun, presumably to elevate *Tb* (Lillywhite *et al.*, 1973; Lillywhite, 1975).

Amphibian thermoregulatory behaviour has been observed in the field and in the laboratory (Brattstrom, 1979), but very little is known concerning pertinent cues for behavioural thermoregulation. Some amphibians living in cool, montane habitats behaviourally elevate *Tb* above ambient (Pearson and Bradford, 1976; Heath, 1975). Some species elevate *Tb* above normal levels after feeding (Feder, 1982; Lillywhite *et al.*, 1973). Tiger salamanders lower *Tb* below normal in response to hypoxia (Dupre and Wood, 1988). *Necturus maculosus* lowers *Tb* and thermal tolerance when injected with melatonin and chlorpromazine (Erskine and Hutchison, 1982; Hutchison, 1981).

The purpose of this study was to examine the effects of exogenous cues—light, time of day and season—on temperature selection in *Bufo marinus*, a resident of lowland tropics where ambient temperatures are fairly stable. The effect of time of day on temperature selection in *Bufo marinus* was compared with that of *Bufo cognatus* a temperate toad which can experience large temperature fluctuations throughout a 24 h period.

It is hypothesized that *Bufo marinus* in a linear thermogradient with a uniform light source would select warmer *Tb* s than toads in the gradient with a point source of light over the hot end of the gradient. *Bufo marinus* occurs in areas where ambient temperatures are stable and therefore should select more constant *Tb* s than temperate *Bufo cognatus*. Because *Bufo cognatus* lives in an environment where it can only be active for a portion of the year it should select higher *Tb* s than *Bufo marinus* to increase digestive rate, growth and fat deposition. *Rana cascadae* tadpoles in a montane environment with a short developmental season utilize warm areas of the pond in the early morning and late afternoon presumably to increase growth (Wollmuth *et al.*, 1987).

MATERIALS AND METHODS

*Bufo marinus* [213.8 ± 47.3 g (mean ± SD)] were obtained from an animal supply company and *Bufo cognatus* [47.0 ± 10.1 g] were collected in the Norman, OK area. Animals were maintained in the laboratory on an LD 12:12 photoperiod with photophase centred at 12.00 h CST. Toads were maintained at an air temperature of 25°C, but could elevate their *Tb* s during the photophase by moving under an incandescent light bulb suspended over one end of the cage. Toads were fed neonatal mice, crickets or mealworm larvae twice per week.

Five days prior to the experimental period the toads were acclimatized in controlled environmental chambers to a constant 25°C and an LD 12:12
photoperiod. Toads were fasted during acclimatization, but were provided a constant source of water.

One day before the experiment each toad was placed into an environmental linear thermal gradient with floor temperatures ranging from 10 to 40°C. Two lighting arrangements were used during the experiment. For the light at the hot end treatment (LH) a point-source of light, a 60 W broad spectrum incandescent light bulb in a reflector, was suspended over the hot end of the gradient. This produced an arrangement where one end of the gradient was light and warm and the other end was cold and dark. For the uniform light treatment (UL) a broad spectrum fluorescent tube was suspended over the entire length of the gradient. This allowed the toad to select for heat levels, but not light intensities.

A 960 ml water container was placed at either end of the gradient behind a styrofoam partition that prevented the toad access to the container. A strip of Handi-wipes (Colgate Co., New York) sewn together to extend the entire length of the gradient sat on the floor of the gradient. The ends of the Handi-wipes were placed in the water containers and acted as wicks which kept the floor of the gradient wet.

The floor of the gradient was made of 0.3 cm thick aluminum which was approx. 18 × 210 cm. The walls of the gradient were 18 cm high and the top of the gradient was covered with a thin sheet of acrylic.

Approx. 0.5 h prior to the experimental period each toad was removed from its thermal gradient and a copper-constantan thermocouple was inserted 1–2 cm into the cloaca. The exiting wire was wrapped in thin-walled polyurethane tubing and was surgically stapled to the dorsal surface of the toad. Body temperatures were monitored at 10-min intervals for 24 h beginning at 12.00 h CST.

In the spring (May–June) one group of B. marinus was exposed to the UL treatment and a second group was exposed to the LH treatment. In the fall (September) one group was exposed to the LH treatment. Also, one group of B. cognatus was subjected to the LH treatment. In all treatment groups the sample size was 8. An equal number of male and female toads were used and no animals were used twice.

A two-way repeated-measures analysis of variance (ANOVA) was used to compare mean $T_b$s among treatment groups and the pattern of temperature selection over time (temporal pattern). Tukey’s test was used to determine which hours of the day toads selected significantly different $T_b$s. Means were considered significantly different at $P < 0.05$.

RESULTS

There were no significant differences in the mean $T_b$s of the B. marinus groups. Neither light treatment nor season influenced means $T_b$s over the 24 h period. The spring UL and LH B. marinus groups showed no differences in $T_b$s during any hours of the experiment (Table 1).

The B. cognatus had higher mean $T_b$s ($P < 0.01$) than the larger B. marinus and chose significantly higher $T_b$s from 16.00 to 17.00 h CST than from 05.00 to 06.00 h CST. The spring UL group had

Table 1. The mean body temperature selected by toads over a 24 h period and SEM

<table>
<thead>
<tr>
<th></th>
<th>Spring</th>
<th>Fall</th>
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<tbody>
<tr>
<td>B. marinus UL</td>
<td>26.7 ± 0.73 No</td>
<td>27.7 ± 1.57 Yes</td>
</tr>
<tr>
<td>B. cognatus LH</td>
<td>24.3 ± 0.96 No</td>
<td>24.3 ± 0.99 Yes</td>
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Yes represents the presence of significant differences in mean $T_b$s body temperatures selected over the 24 h period.

Fig. 1. Temperature selection of B. marinus and B. cognatus over a 24 h period in a linear thermal gradient. Each circle is the mean body temperature of 8 toads over a 1 h interval. Vertical lines represent 1 SE above the mean. Dark horizontal lines represent the scotophase.
slightly (2.4°C) but not significantly higher mean \( T_s \) than the spring LH group over the 24 h period (Table 1, Fig. 1).

**DISCUSSION**

Contrary to the author's prediction, *B. marinus* did not select significantly higher mean \( T_s \) in the UL condition than in the LH condition. Although the UL group showed slightly elevated \( T_s \)s over the 24 h period and very constant \( T_s \)s throughout the test period, there was no evidence to support the hypothesis that in *B. marinus* temperature selection was a function of light position. The \( T_s \)s during some portions of photophase were significantly lower than \( T_s \)s during some portions of scotophase for the fall LH control group (Table 1). The spring LH group showed the same trend of lower photophase \( T_s \)s, but the difference between day and night \( T_s \)s was not significantly different. This pattern was absent in the UL group which could not select for light intensity. Rather than influencing mean \( T_s \), light may play a role in how temperature is selected over time (Fig. 1).

Time of day is an important factor in temperature selection in reptiles (Sievert and Hutchison, 1989), but this has not been demonstrated in many amphibians. *N. maculosus* showed a diel cycle in temperature selection with the highest preferred \( T_s \) occurring during scotophase, the animals' activity period (Hutchison and Spriesterbach, 1986). *Rana piniens* tadpoles exhibited a bimodal cycle of temperature selection. Mean photophase and scotophase \( T_s \)s did not differ, but \( T_s \) decreased during the switch from scotophase to photophase (Casterlin and Reynolds, 1978). In other species of amphibians no diel cycles of temperature selection have been observed (Lillywhite, 1971; Woolsnith et al., 1987; Kluger, 1972). Some species of amphibians may display diel cycles of preferred temperature and others may not.

An alternate possibility is that the presence or absence of diel cycles in temperature selection may be a function of exogenous factors such as light and season. This would appear to be the case with *B. marinus*. During the spring the LH group showed no significant difference in temperature selection over time, whereas in the fall the LH group did show significant differences in \( T_s \) over time. The mean selected temperature was not influenced by season. This is in contrast to tadpoles (*R. piniens* and *R. catesbienia*) and mudpuppies which showed seasonal shifts in preferred temperature (Lucas and Reynolds, 1967; Hutchison and Spriesterbach, 1986).

In reptiles the highest \( T_s \)s are selected during activity for both diurnal (Sievert and Hutchison, 1989) and nocturnal lizards (Sievert and Hutchison, 1988; Bennett and John-Alder, 1986). *B. marinus* is primarily nocturnal and the highest \( T_s \)s in the LH groups were selected at night. Peak levels of oxygen consumption also occurred at the onset of scotophase in *B. marinus* acclimated to the LD 12:12 photoperiod. This cycle of oxygen consumption was a function of alternating light and dark periods and was absent under LL or DD conditions (Hutchison and Kohl, 1971).

*B. cognatus* selected higher \( T_s \)s than *B. marinus*, particularly during photophase. Unlike *B. marinus* which selected their coolest \( T_s \)s during midphotophase, *B. cognatus* chose their coolest \( T_s \)s during late scotophase. The difference in mean \( T_s \) was not due to size alone. The *B. cognatus* spent more time in the hotter parts of the gradient and both species could readily elevate their \( T_s \)s to over 30°C.

In summary, the mean selected \( T_s \)s in *B. marinus* over a 24 h period were not influenced by season or light regime. In contrast, the pattern of temperature selection over a 24 h period was altered by season in the LH groups. The temperate *B. cognatus* selected significantly higher mean \( T_s \)s over a 24 h period than the tropical *B. marinus* in the fall. The pattern of temperature selection over time was different between the two species. The *B. cognatus* selected their lowest \( T_s \)s during late scotophase and the *B. marinus* selected their lowest \( T_s \)s during midphotophase.

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**REFERENCES**


