

## LIGHT VERSUS HEAT: THERMOREGULATORY BEHAVIOR IN A NOCTURNAL LIZARD (*GEKKO GECKO*)

LYNNETTE M. SIEVERT AND VICTOR H. HUTCHISON

*Department of Zoology, University of Oklahoma, Norman, OK 73109, USA*

**ABSTRACT:** Tokay geckos (*Gekko gecko*) acclimatized to  $25 \pm 1$  C and a LD 12:12 photoperiod exhibited significant diel cycles of temperature selection in a thermal gradient with either uniform light over the entire gradient (UL) or a point-source of light over the hot end of the gradient (LH). Both groups selected higher body temperatures at night than during the day. No diel cycle was observed in the geckos exposed to the paradoxical condition of a point-source of light over the cold end of the gradient (LC). The UL and LH groups showed greater precision in thermoregulation during the scotophase than during the photophase. The opposite was found for the LC group. We concluded that light has a definite impact on thermoregulatory behavior that is distinct from the role that heat plays in thermoregulation. We recommend that variance be used as a standardized measure of thermoregulatory precision.

**Key words:** Behavior; Thermoregulation; Gekkonidae; Light; Diel; Precision; Cycles; Preferred temperature; *Gekko gecko*

MANY authors have studied reptilian thermoregulation and preferred temperature (= selected temperature) in reptiles (for reviews see Avery, 1982; Brattstrom, 1965; Dawson, 1975; Huey, 1982). Most previous work was done with heliothermic lizards. Firth and Turner (1982) noted the need for information on the influence of light on behavioral thermoregulation in reptiles; they believed that light influenced thermoregulation in ways beyond the provision of a heat source. Ballinger et al. (1969) suggested that the relationship between thigmothermal and heliothermal responses needed to be determined. Despite these suggestions, no one has studied how light influences behavioral thermoregulation apart from its provision of heat.

Because of the inconsistency in methodology employed in studies of temperature selection in reptiles in gradients, results from different studies are hard to compare. If light is indeed a distinct factor that influences behavioral thermoregulation, then comparing data gathered from thigmothermal gradients with data from photothermal gradients (where a light is also the heat source) is useless. In the former case, one assumes that temperature selection under laboratory conditions is based solely on ambient temperature and is completely separate from selection for light. In the latter case, it is impossible to

determine if light had any effect on temperature selection.

Another inconsistency in methodology involves the time of day during which the study was done. Some studies were performed during the animal's activity period (Gleeson, 1981; Licht et al., 1966), and others during the inactive period (Vance, 1973).

Because few investigations have been made on nocturnal lizards during their activity phase, little is known about how light may affect behavioral thermoregulation of these lizards. Our purposes were to determine the effects of the: (1) position of the light source in relation to the position of the heat source on the preferred temperature of a nocturnal lizard; (2) time of day on the temperature preference of a nocturnal lizard; and (3) time of day on precision of thermoregulation. We hypothesized that both the position of the light source and time of day would affect the preferred temperatures of these lizards and that precision would be greatest during the activity period.

### MATERIALS AND METHODS

Ten *Gekko gecko* (14–23 cm snout–vent length) were purchased from a local pet dealer and were maintained for at least 2 mo prior to experimentation in the laboratory (21–24 C) on a LD 12:12 photo-

period centered at 1200 CST; the light was provided by incandescent 60-W bulbs. Five days before the experimental period each lizard was acclimated to  $25 \pm 1$  C and maintained on the same LD 12:12 photoperiod with the photophase centered at 1200 CST. During acclimation the lizards were given water ad lib, but no food.

Thirty minutes before the onset of the experimental period, a 30-gauge copper constantan thermocouple wrapped in thin-walled flexible polyethylene tubing was inserted approximately 2 cm into the cloaca and the exiting thermocouple wire was taped to the lizard's tail. Body temperatures were recorded every 10 min throughout the 24-h experimental period on an Instrulab 2000 Data Logger. Body temperatures were recorded for 24 h starting at noon.

Lizards were placed singly in each of three linear thigmothermal gradients with aluminum plate (0.3 cm) floors. Each gradient was approximately 210 cm long, 22 cm high, and either 20 or 23 cm wide and had substrate temperatures ranging from  $15 \pm 0.2$  C to  $45 \pm 2.0$  C. Gradients were housed in an environmental room maintained at  $15 \pm 0.5$  C; the cold end of the gradient was at the same temperature. A hot plate and a heating pad kept the hot ends of the gradients at 45 C. Each gradient was covered by a heat shield of clear acrylic plastic (Fig. 1) which prevented measurable heat from the lights from entering the gradient.

One gradient had broad spectrum fluorescent lights (General Electric) suspended over it which provided uniform light over the entire length of the gradient (UL). The other gradients had a point-source of light over the hot end (LH) or the paradoxical situation of a point-source of light over the cold end (LC). Each point-source of light was provided by one broad spectrum 60-W incandescent bulb (Westinghouse) with a narrow reflector shade such that light fell directly on a 15-cm diameter circle at the end of the gradient. With the point-source of light, intensity decreased down the length of the gradient and beyond 64 cm from the light end, the gradient was dark. The gradient lights pro-

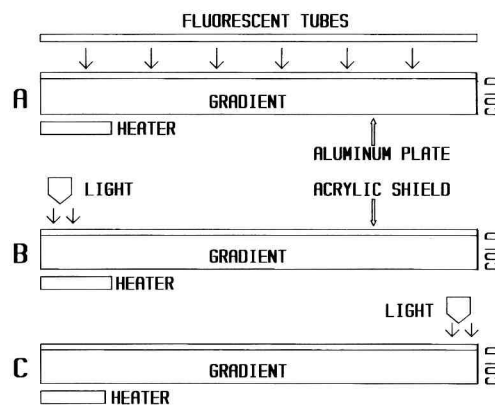


FIG. 1.—Laboratory thermal gradients used to study thermal selection in *Gekko gecko*. A = uniform light (UL); B = point-source of light over the hot end (LH); C = point-source of light over the cold end (LC). Substrate temperatures ranged from 15–45 C.

vided the only source of light in the room. All lights were on a LD 12:12 photoperiod during the experiments.

Each of the 10 geckos was tested with each of the three light treatments. We randomized the order in which lizards were exposed to each treatment. Due to equipment failure, results were only available for nine geckos in the LH treatment group. If a lizard became tangled in or became detached from the thermocouple, the body temperature values were not included in data analyses. No attempt was made to determine the sex of the lizards. The study was conducted from October 1985 to January 1986. Each lizard was allowed several weeks between uses as an experimental subject. All animals were healthy and alert during the experimental period.

We used a two-factor (light treatment and time) repeated measures experimental design. The repeated measures on individuals were necessary because in each treatment group the lizards were observed over all 24 1-h time blocks. The lizards were defined as a third factor having 10 levels. As such, the "lizard" factor was crossed with the "time" factor but nested under the "light treatment" factor. In this experiment, the "light treatment" had 3, and the "time" factor 24, levels.

We applied a two-way with repeated measures analysis of variance (ANOVA)

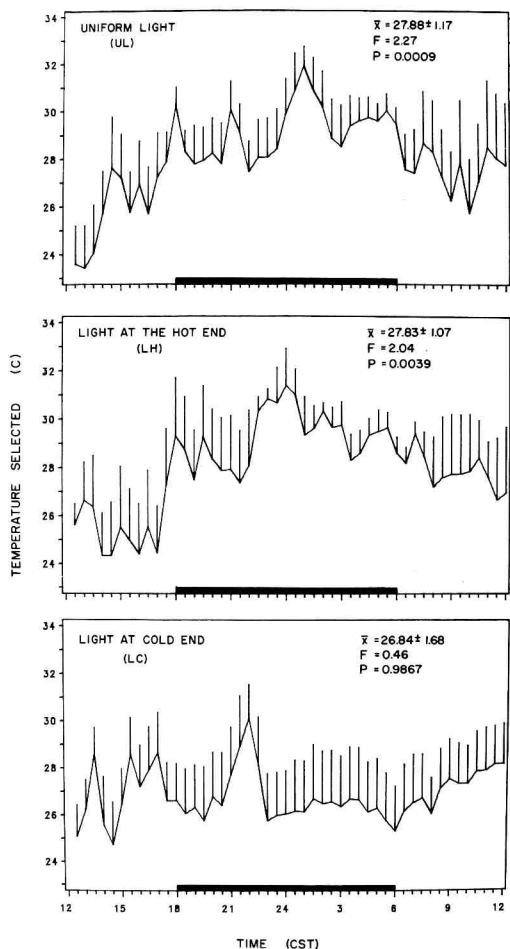


FIG. 2.—Temperature selection of *Gekko gecko* over a 24-h period in a thermal gradient after acclimatization to  $25 \pm 1$  C and a LD 12:12 photoperiod. Mean body temperatures are plotted at half-hour intervals. Vertical lines represent one SE above the mean. The black horizontal bars indicate scotophase.

procedure to these data. We examined differences in body temperatures among the light treatment groups, among body temperatures within each group over time, and in temporal patterns of thermoregulation among groups (interaction of treatment versus time).

One problem with the application of an ANOVA to our data was the inequality of body temperature variances. However, because ANOVA is a robust test, such minor violation of the equal variance assumption should not invalidate the results (Winer, 1971). A two-way ANOVA with repeated

measures was used because it does not make the assumption of independence of samples over time (Mathur and Silver, 1980). Because this ANOVA allows no missing data, we had to provide values for occasional missing data points on individual animals due to inoperative thermocouples. We used the average of other lizards' body temperatures within the same treatment group at the time of the missing data for the missing values. Nonparametric procedures were not used because they require rank-order measurements which are inappropriate for interval scaled measurements such as body temperatures; information would be lost when interval measure is transformed to rank order.

We used a Tukey's studentized range test (SAS, 1982) on 24 1-h time blocks to determine if body temperature varied over time within each treatment group. Precision of thermoregulation was defined as the variance of the mean selected temperature for a given time period. Variance was calculated at 0.5-h intervals and pooled to give 6-, 12-, and 24-h time blocks. An  $F_{\max}$ -test (Sokal and Rohlf, 1981) was used to test for differences in precision. Differences were considered significant at  $\alpha = 0.05$ .

## RESULTS

The position of the lights over the gradient had a significant effect on thermoregulatory behavior. Grand mean body temperatures over 24 h ( $\pm$  SE) of the UL ( $27.88 \pm 1.17$  C), LH ( $27.83 \pm 1.07$  C), and LC group ( $26.84 \pm 1.68$  C) did not differ significantly (Fig. 2). Time of day had a significant ( $P < 0.0001$ ) effect on thermoregulatory behavior. The pattern of temperature selection over time was significantly different ( $P = 0.0029$ ) among the groups.

Time of day significantly affected body temperatures selected except in the LC treatment group (Fig. 2). For both the UL and the LH groups, the lizards chose higher mean body temperatures during some portion of the scotophase than during some portion of the photophase. For the UL group, significantly higher mean body temperatures ( $P < 0.05$ ) were selected from

TABLE 1.—Effects of light placement on precision of behavioral thermoregulation of *Gekko gekko* in a laboratory gradient (15–45 C). Precision is given as the variance of mean selected temperatures; lower values indicate greater precision.

Treatment	Time block	Precision	$F_{max}$	df	$P$
Uniform light (UL)	Entire day	22.60	—	366	—
	Photophase	28.17	1.932	181	<0.01
	Scotophase	14.58			
	1200–1800 h	30.31	2.938	79	<0.01
	2400–0600 h	10.32			
	0600–1200 h	23.78	1.411	66	>0.05
1800–2400 h	16.85				
Light at hot end (LH)	Entire day	24.08	—	325	—
	Photophase	28.55	1.793	156	<0.05
	Scotophase	15.93			
	1200–1800 h	33.26	6.790	72	<0.01
	2400–0600 h	4.90			
	1800–2400 h	25.40	1.297	70	>0.05
0600–1200 h	19.59				
Light at cold end (LC)	Entire day	29.65	—	431	—
	Scotophase	34.98	1.427	212	>0.05
	Photophase	24.51			
	2400–0600 h	37.83	1.676	106	<0.05
	1200–1800 h	22.56			
	1800–2400 h	32.15	1.213	104	>0.05
0600–1200 h	26.50				

2400–0100 h ( $30.3 \pm 1.06$  C) and 0100–0200 h ( $31.4 \pm 0.79$  C) than from 1300–1400 h ( $23.7 \pm 1.30$  C). For the LH group significantly higher mean body temperatures were selected from 2400–0100 h ( $31.2 \pm 0.90$  C) than from 1400–1500 h ( $24.3 \pm 1.36$  C). These were the only times that were significantly different from each other. The LC treatment group did not select significantly different ( $P > 0.05$ ) body temperatures at any time of the day (Fig. 2).

Precision varied greatly with time of day, and the position of the light over the gradient had a definite impact on precision (Fig. 1, Table 1). The UL and the LH groups thermoregulated significantly more precisely ( $P < 0.01$ ) during the scotophase than during the photophase. The greatest differences in precision were found when the second half of scotophase (2400–0600 h) was compared with the second half of photophase (1200–1800 h). The LC group showed an entirely different pattern of precision in thermoregulation. In this group, greater precision occurred during photophase than during scotophase (Fig. 3, Table 1). There were no significant differences in precision among the treatment

groups when they were compared over the entire 24-h period.

#### DISCUSSION

Most studies on body temperatures of geckos have been done under field conditions (Avery, 1982) where the lizards may not have been able to maintain a “preferred” body temperature. Large differences between laboratory and field body temperatures may occur in nocturnal geckos (Licht et al., 1966). These authors found differences ranging from 5–20 C between field and laboratory body temperatures and suggested that the laboratory values reflected preferred temperatures while the field values reflected the range of body temperatures tolerated during activity. Dial (1978) suggested “that activity temperatures at night are suboptimal and that difference between preferred and activity temperatures might represent a compromise” in nocturnal geckos.

Marcellini (1976) believed that the nocturnal *Hemidactylus frenatus* did not have a preferred body temperature but a “range” of body temperatures over which it could be active. Some nocturnal geckos

