Ultraviolet Light and Heat Source Selection in Captive Spiny-Tailed Iguanas (*Oplurus cuvieri*)

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Three experimental manipulations were conducted to assess the influence of heat source selection and active thermoregulation on ultraviolet (UV) light exposure in captive spiny-tailed iguanas (*Oplurus cuvieri*) at the Jersey Wildlife Preservation Trust. Four replicates per manipulation were conducted on six individual lizards. All animals were tested in a separate enclosure to which they were acclimated before observations. Data on choice of thermal sources were collected during the first 2 hr of light, when lizards were actively thermoregulating. Animals were allowed to choose between incandescent light, UV light and a non-light heat source (thermotube) in different combinations. Recorded temperatures close to the incandescent light (37ºC) were always significantly higher than at the thermotube (33ºC) and at the UV light (29ºC).

Manipulation 1 offered the animals a choice of an UV light and an incandescent light as thermal sources. Manipulation 2 presented animals with the thermal choices in Manipulation 1, but substrates under each source in Manipulation 1 were switched. In Manipulation 3, animals could choose between an incandescent light and the thermotube.

All studied lizards were significantly more attracted to the incandescent light than to the UV light or thermotube. Incandescent light elicited a significantly higher proportion of basking behaviors in all individuals than the other sources. A high proportion of time basking was also spent in front of the thermotube but fewer individuals and less time were spent basking under the UV light. Heat source selection was generally found to be independent of substrate. Management applications of this preference are suggested for juvenile diurnal heliothermic iguanids. Zoo Biol 16:391–401, 1997.   © 1997 Wiley-Liss, Inc.

Key words: thermoregulation; heat-light preference; lizards

INTRODUCTION

Optimal body temperatures in lizards are regulated by moving into sunshine or hot surfaces when too cool and into shade when too hot [Huey, 1982; Mattison, 1989]. Such behavioral thermoregulation is critical to the survival of species, especially those found in habitats with widely varying temperature patterns [Avery, 1984].

In the wild, direct solar radiation is not only a main source of heat, but also of ultraviolet (UV) light. UV light increases activity in lizards and snakes, and exposure to certain wavelengths is essential to the health of diurnal lizards [Blatchford, 1986]. The latter is because UV light is linked to the synthesis (photobiogenesis) of vitamin D^3. This vitamin is necessary for the metabolism of dietary calcium since hypovitaminosis-D leads to rickets and osteomalacia. Other effects of a calcuim imbalance are the production of poorly calcified eggs, unusually high numbers of nonviable eggs, and poor hatching success [Wallach, 1986].

It was not until the advent of Vitalite fluorescent tubes (although UV lighting was first used as early as 1923) that UV has been consistently included in captive reptile management [Laszlo, 1969]. However, despite the fact that providing UV lights has resulted in major improvements, most collections still suffer from complications resulting from hypovitaminosis-D. A way of overcoming this problem has been to provide animals with oral sources of vitamin D^3 [Brice, 1995]. The occurrence of hypovitaminosis-D may be the result of poor design and maintenance of UV lighting, but also that reptiles are not choosing to spend enough time under these lights.

Given the choice of basking under the normally hotter incandescent white lights or a separate cooler UV light, as is typical in most reptile enclosures, animals may bask preferentially under the hotter source and thus receive inadequate UV radiation. Although research on the effect of lighting on behavioral thermoregulation and activity patterns has been reported for some captive lizards (*Crotaphytus collaris* [Sievert and Hutchison, 1991]; *Phelsuma guentheri* [Wheeler and Fa, 1995]), no work has been undertaken to determine the degree of preference for light, heat, or UV sources. The present study is aimed at establishing the relative behavioral attractiveness of different sources of photothermal (heat-light) radiation offered to juvenile spiny-tailed lizards (*Oplurus cuvieri*) (Family: Iguanidae) in captivity. Preference for different thermal sources was investigated by quantifying the use of the enclosure space by the study animals and by observation of basking behaviors associated with each source. The results may be applied to the management and enclosure design of captive populations of other diurnal heliothermic lizards. It can also help clarify the contribution that behavioral cues can make to the maintenance of healthy reptiles in captivity.

METHODS

Study Animals And Environment

A group of six first-generation, captive-born unsexed juvenile spiny-tailed lizards was used in the present study. The captive population of *Oplurus* was established at the Gaherty Reptile Breeding Centre (GRBC) at the Jersey Wildlife Preservation Trust (JWPT) in 1990. This arboreal species is found in dry deciduous forests in northwestern Madagascar [Obst et al., 1984]. The spiny-tailed iguana is a diurnal heliotherm. All study lizards were in good health; Lizard 4 molted during Manipulation 1, and Lizard 5 lost the tip of its tail in an aggressive encounter with

Lizard 4 prior to Manipulation 3. Animals were normally kept in three Plexiglas cages (two per cage) in an off-exhibit area. Lizards were fed on live crickets (supplemented with a calcium-balancer and multivitamin powder, Nutrobal, Vetark Animal Health, P.O. Box 60, Winchester, Hants SO23 9XN, U.K.), 2–3 afternoons per week. Water was available continually on an ad libitum basis. Animals were marked with paint for individual recognition, weighed, and acclimated to the study enclosure 15–21 hr prior to the observation period. Individuals in the study enclosures were not in visual contact with the other animals or with any external light source.

Temperature Records

Thermogradients within the enclosures were recorded by placing dry-bulb thermometers at ground level and at a height of 15 cm in the left, center, and right of the enclosure. Prior to manipulations, heat dissipation from each thermal source was measured by taking temperatures ($n = 10$) at 10-cm intervals (0–100 cm) away from each source. Ambient and enclosure temperatures were also registered at the start and end of each observation period.

Use of Space

The study enclosure was divided into 40 grid cells (231 cm^2 each), which were used to identify the subject lizards' position during each scan sample. The lizard's location was taken as the cell in which >50% of its body was found.

Basking Behavior

In all manipulations, the lizards' orientation under the photothermal sources was recorded during scan samples. Individual lizard directional choices were described as (a) active basking; (b) body parallel to the source; (c) body perpendicular to the source. Active basking was assumed to occur when the animal sprawled on a substrate with legs outstretched and flattened ribcage and its entire body directly under the photothermal source. This position maximizes the body surface area exposed to the incident radiation. A body position perpendicular to the photothermal source offers minimum body surface area for irradiation, whereas parallel position offers an intermediate area for heat absorption.

Manipulations

Three separate heat-light selection manipulations were undertaken. Each individual animal was tested in four separate occasions per manipulation. Because all lizards received all manipulations, the sequence of testing was varied among individual animals to control for sequence effects. The position of the incandescent light within the enclosure was changed during Manipulation 3 to control for habituation to a particular area of the enclosure. Observations were conducted from October 30 to December 8, 1995; 12 days per manipulation. Data were collected for the first two hr (between 08:00 and 10:35) of the autumn light (9 hr); dark (15 hr) regime, a period immediately after night emergence. This is when lizards are likely to be most actively thermoregulating to warm up to their activity temperature [Avery, 1976].

For all manipulations, instantaneous scan samples at 5-min intervals were used to record an individual's use of the enclosure, orientation towards the light sources, behavior, and use of substrate. A total of 72 observation hr was collected; 194 gross data points per individual per manipulation. Lizards were tested in separate study

enclosures (154 × 60 × 32 cm, with Plexiglas fronts), similar to those used for housing. All enclosures had gravel floors and contained rocks and branches and two water dishes.

Manipulation 1 – Light Source Selection

The aim of this manipulation was to investigate the lizards' preference for two photothermal sources: (a) a full spectrum (300–500 nm) incandescent light (Philips 40 W Reflector R63 bulb) on the enclosure front (Cell C1), focused downwards 13 cm above a rock substrate and (b) a UV light (Philips TLD 15W/05, 43.5-cm tube, 370–410 nm) suspended above side D (Cell C9) of the enclosure (see Fig. 1). A log substrate was placed adjacent to the UV light.

Manipulation 2 – Influence of Substrates on Light Preference

In this Manipulation the effect of substrate on choice of photothermal sources was studied. Because there are clear heat conductance differences between rock and log, thigmothermy may have influenced thermal source choice. Thus, the same photothermal sources as in Manipulation 1 were used, but the location of the rock and log substrates was reversed.

Manipulation 3 – Photothermal of Thermal Source Preference

To separate the influence of light and heat on thermal source preference, in this manipulation the UV light source was substituted by a non-light heat source (Philips Thermotube 240V/60W, 30.5 cm). This was suspended 13 cm above a log substrate. Lizards had to choose between the incandescent light source and the thermotube. The incandescent light beam was focused onto a log substrate. Both heat sources provided similar temperatures (32ºC).

Statistical Analysis

In all manipulations, only observations in which the lizard was visible were considered in the analyses. To describe objectively the level to which lizards aggregated around the photothermal sources, a standardized Morisita index of dispersion (Ip) was employed [Krebs, 1989]. The standardized Morisita index measures clumping of the lizards' use of the full set of enclosure cells. The Ip ranges from –1.0 to +1.0, where random patterns give Ip of zero, clumped patterns above zero, and uniform patterns below zero. This measure has been shown to be independent of sample size [Krebs, 1989]. Individual preferences for particular grid cells as well as the frequency of occurrence of body orientations to the different sources were tested using χ^2 tests. The effect of substrate on thermal source selection was determined using a fourfold χ^2 contingency table [Siegal and Castellan, 1988]. Temperature differences between basking and non-basking sites were analyzed using Student's t-test [Zar, 1984].

RESULTS

Temperatures

Room temperature increased significantly form start to end of the two-hr observation periods (t = 24; 29 df; $P < 0.001$). The mean starting room temperature
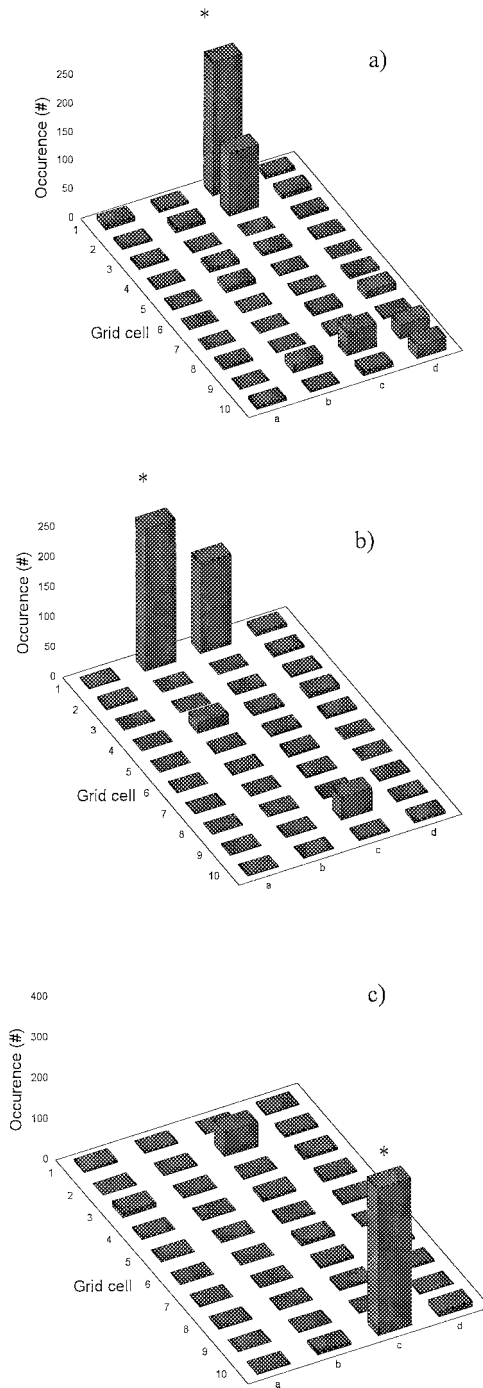
Fig. 1.   Frequency of grid cell use for pooled data for all lizards in: a) Manipulation 1; b) Manipulation 2 and c) Manipulation 3. Asterisk denotes the position of the incandescent light.

was 25.1±0.9ºC (maximum: 27.5ºC; mode: 24.5ºC) and rose to 28.4±0.6ºC (maximum: 29.5ºC; mode: 28.5ºC) at the end of observations.

Temperatures were highest around the area of the test enclosures where the incandescent light was placed (upper half: 27.6±0.6ºC; lower half: 28.6±0.5ºC), but were similar in the opposite end (upper half: 26.1±0.3ºC; lower half: 26.8±0.5ºC) and center (upper half: 26.5±1.3ºC; lower half: 26.6±0.5ºC). Highest mean temperatures (37.3±0.9ºC) were typical by the incandescent light, but significantly lower adjacent to the thermotube (32.5±0.8ºC), and even lower around the UV light (29.0±0.6ºC) (incandescent/thermotube comparison: t = 3.55, 16 df, $P < 0.001$; incandescent/UV comparison: t = 8.9, 16 df, $P < 0.001$). The UV light temperatures were also significantly cooler than those at the thermotube (t = 25.8; 16 df; $P < 0.001$). Temperatures under the incandescent light were also significantly hotter than elsewhere in the enclosure (t = 5.41; 16 df; $P < 0.001$).

Mean temperatures fell significantly (7º for the incandescent light and around 3º for the thermotube and UV light) at distances of 20+ cm from the source. Beyond 20 cm, temperatures remained relatively constant at 28ºC, away from the thermotube, and 25ºC away for the UV light. In contrast, temperatures dropped by 2º at 20 cm and by another 2º at 40 cm away from the incandescent light, before remaining constant at 26–27ºC.

Light Source and Substrate Selection

In Manipulation 1, a maximum of 17 grid cells (42.5% of total grid cells, individual range: 10–17 cells) were used by all lizards. All individuals exhibited a clumped use of the enclosure where only one or two grid cells were occupied (Fig. 1a), as indicated by high Ip values (Table 1); mean ± S.D., Ip: 0.67±0.12, range: 0.50–0.90. All individuals demonstrated a significant preference for grid cells under the incandescent light.

Significantly clumped enclosure use was observed for all lizards in Manipulation 2 (Fig. 1b) (Ip: 0.80±0.28, 0.60–1.40) (Table 2). The maximum number of grid cells used by all lizards was 13 (32.5%; individual range: 6–13 cells). As in Manipulation 1, most clumping occurred around the incandescent light.

Pooled data from Manipulation 1 and 2 were used to determine whether light source selection was affected by substrate. Results of the fourfold contingency test indicated that four of the six study lizards selected the incandescent light source independent of the substrate (Lizard 1: $\chi^2 = 5.1$, df 6, $P < 0.001$; Lizard 3: $\chi^2 = 6.43$, 6 df, $P < 0.001$; Lizard 4: $\chi^2 = 12.5$, 6 df, $P < 0.001$; Lizard 6: $\chi^2 = 9.9$, 6 df, $P < 0.001$), but for the two remaining animals, substrate had a significant effect (Lizard 2: $\chi^2 = 1.83$, 6 df, NS; Lizard 5: $\chi^2 = 1.1$, 6 df, NS).

Photothermal vs. Thermal Source Selection

Significant clumping was also demonstrated by all lizards when given the choice between the incandescent light and the thermotube; Ip values of 0.76±0.08, 0.66–0.89 were recorded (Fig. 1c, Table 1). A maximum of 15 of 40 grid cells were used by individual lizards (individual range: 8–15 cells used). Most clumping occurred in cells below the incandescent light.

Basking

Pooled data (n = 733) for Manipulations 1 and 2 showed that lizards did not actively bask more often under incandescent light (52.1% of records) than under UV

TABLE 1. **Summary statistics for testing clumping, and preference for certain grid cells, using the standardized Morisita Index of Dispersion**

Manipulation	Individual	Ip	n	df	χ^2 Statistic
1. Light source selection	1	0.7	93	39	1,522
	2	0.5	85	39	409
	3	0.5	93	39	995
	4	0.7	96	39	1,463
	5	0.9	96	39	2,403
	6	0.6	94	39	568
	Mean ± S.D. 0.67 ± 0.12				
2. Substrate preference	1	1.4	97	39	1,991
	2	0.7	76	39	1,162
	3	0.6	56	39	398
	4	0.6	96	39	915
	5	0.7	83	39	1,578
	Mean ± S.D. 0.80 ± 0.28				
3. Photothermal vs. thermal source selection	1	0.66	86	39	1,120
	2	0.79	89	39	2,089
	3	0.78	92	39	2,118
	4	0.66	93	39	1,179
	5	0.89	84	39	2,602
	6	0.75	92	39	1,851
	Mean ± S.D. 0.76 ± 0.08				

TABLE 2. Results of Manipulations 1–3 assessing active thermoregulation by individual lizards under each heat-light source

	Source	Lizard	n	df	χ^2 Statistics
Manipulation 1 and 2	Incandescent light	1	155	3	103*
		2	104	3	93*
		3	91	3	24.7*
		4	94	3	4.8 NS
		5	155	3	80.8*
		6	102	3	58.4*
	UV light	1	8	3	7*
		2	14	3	12*
		3	23	3	4.2 NS
		4	1	3	3 NS
		5	3	3	1 NS
		6	33	3	77.9*
Manipulation 3	Incandescent light	1	49	3	9.5*
		2	69	3	40.8*
		3	71	3	26.5*
		4	34	3	38.7*
		5	75	3	188*
		6	67	3	5.9*
	Thermotube	1	6	3	5.9 NS
		2	0	3	No data
		3	3	3	9*
		4	42	3	89.6*
		5	1	3	3 NS
		6	8	3	17*

NS = $P > 0.05$, *$P < 0.001$–0.005

light (36.3%) (χ^2 = 2.81; 1 df; P < 0.1) (Fig. 2a). However, a significantly higher proportion of non-basking behaviors was observed under UV light compared to incandescent light (χ^2 = 6.9; 1 df; P < 0.01). In Manipulation 3, significantly more active basking was observed under the thermotube (86.9%) than under the incandescent light (51.3%) (χ^2 = 10.1; 1 df; P < 0.005) (Fig. 2b).

Among lizards, active basking under incandescent light was significantly more frequent than any other body posture in Manipulations 1 and 2 (Table 2). In contrast, under UV light, significantly more active basking than other postures was observed in only three lizards. When given the choice between photothermal and thermal sources in Manipulation 3, only three lizards showed a significant orientation towards the thermotube, yet all lizards were significantly orienting to the incandescent light (Table 2).

DISCUSSION

The present study focuses on an important issue in captive reptile management that needs resolution. Because of limited availability of subjects, a usual impediment in zoo biology, our experiments used siblings. This may have resulted in reduced variability in the sample, compared to a situation which employed non-siblings. Alternatively, the reduced genetic variation may increase support for a true experimental effect. However, because behavioral thermoregulation is such a pervasive feature of reptiles, the results of the reported thermal choice are likely to be relevant to other groups of the same species and even to other species. Further studies should be undertaken with non-related animals to show the robustness of the phenomenon.

Time spent under each photothermal source by the study lizards showed animals preferred incandescent light over the thermotube and UV light. The manipulations also demonstrated that preferences for the thermal source were not influenced by the substrate on which the lizards were basking. The most obvious explanation for the observed radiative source preferences in the present study is that lizards chose the hotter source independent of its spectral qualities. Lizards either prioritize heat over UV absorption (i.e., lizards can UV-regulate) or lizards react purely on the basis of temperatures (i.e., exclusive thermoregulation). Furthermore, because hard UV light sources produce virtually no visible light [Blatchford, 1987], the observed preferences for incandescent light may be attributed to orientation to white light rather than to a hotter source. Thus, choice of basking lights in captivity may be influenced by the presence of visible light and not temperature gradients. This seems intuitively correct because *Oplurus*, as a diurnal heliotherm, may have evolved to cue to a photothermal source for thermoregulation since in nature, heat, light, and UV originate from one source (the sun).

The selection of incandescent light over UV light and non-light heat sources can offer practical applications for management of captive lizards. The use of a combination of UV light paired with incandescent light will no doubt ensure that individuals receive UV irradiation and heat while basking. Providing UV irradiation in this way is more natural, and ultimately more economical. It could minimize the risk of hypervitaminosis-D and reduce dependency and costs of vitamin supplementation. The development and use of halogen bulbs, which provide heat in combination with a proximate UV source, may provide the best solution to the problem.

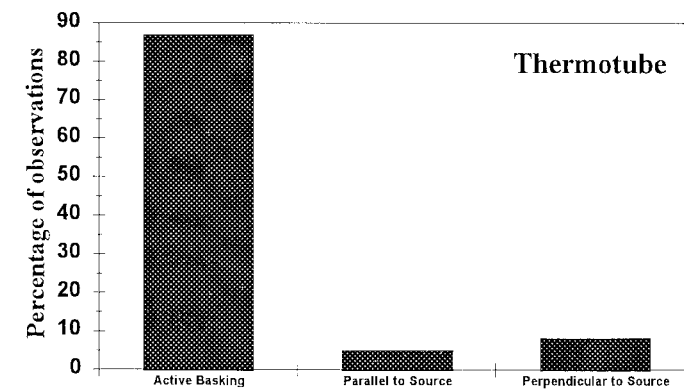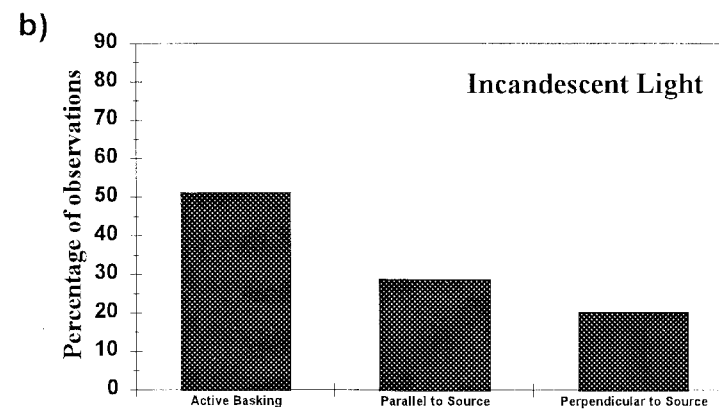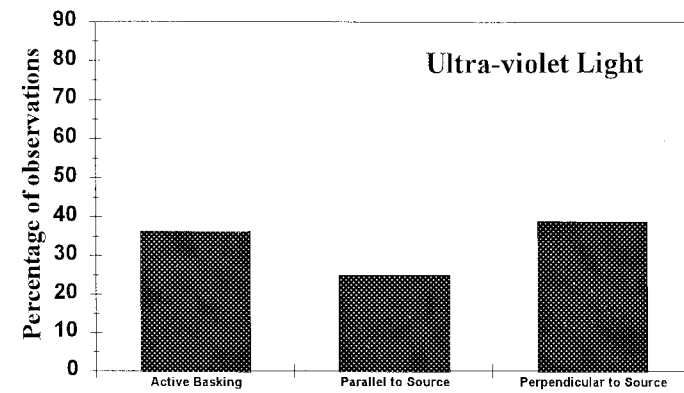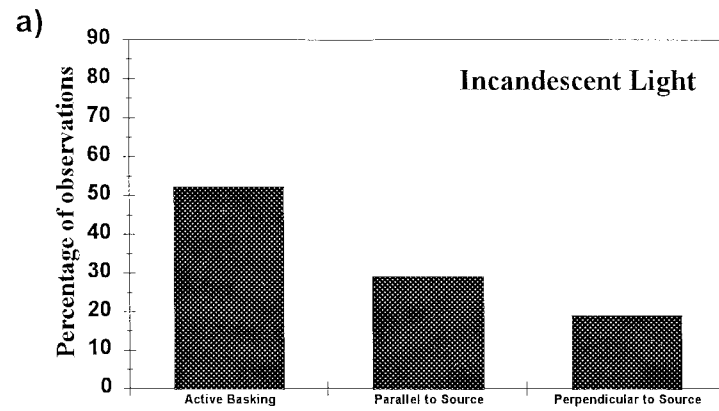A departure from the current practices of flooding enclosures with UV strip

Fig. 2.   Orientation of individual lizards (pooled data) in: a) Manipulation 1 & 2; b) Manipulation 3.

lights in the hope that UV absorption will occur is necessary. Future research must study more closely the internal mechanisms motivating exposure to UV sources. For example, the influence of level of vitamin D nutritional status of the animal must be studied. Panther chameleons have been shown to behaviorally respond to UV light and do this more strongly when their dietary intake of vitamin D is low [Jones et al., 1996]. Similar manipulations should be carried out on other species (such as a nocturnal species or a canopy-dwelling species) to improve enclosure design and management practices. This will have to be done in conjunction with the need to provide the reptile with adequate temporal and spatial choices of light, heat, and UV sources within enclosures [Gehrmann, 1994].

CONCLUSIONS

1. *Oplurus* is attracted to the hottest source provided within the experimental design.

2. Light intensity or quality may or may not be involved in the attraction.

3. Heat without light can stimulate basking behaviors.

4. Future experimental designs should incorporate a higher UV emitting light source and a non-light heat source offering a higher temperature than an incandescent light to verify the observed preference for incandescent light.

ACKNOWLEDGMENTS

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