Time of day predicts the activity budget in the Emerald Tree Boa (Boidae: *Corallus batesii*) across multiple behaviors

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Abstract

Exploring the spatial ecology and behavior of organisms is essential to understand an organism's niche and how to better accommodate animals that are kept in captivity (Ross et al., 2011; Plowman, 2003). Emerald Tree Boas (*Corallus batesii*) are commonly kept as pets and are important predators in the Amazon; however, despite their commercial exploitation and ecological importance, little is known about their behavior. This paper attempts to fill this literature gap by quantifying the behavior of a juvenile *Corallus batesii.* The activity budget of the snake was video recorded over a period of three months and was coded using the event logging software, BORIS (Friard & Gamba, 2016). After conducting individual regression analyses on five behaviors (hunting, moving, resting, other: stationary, and out of view), it was found that time of day significantly predicted the behaviors of hunting ($p=0.0178$, $df=23$, $t=8.50$) and resting ($p=0.00337$, $df=23$, $t=3.52$). Hunting behavior was observed between the hours of 2200 h and 700 h and resting between 800 h and 2100 h.

Introduction

Emerald Tree Boas (*Corallus batesii*) have previously been anecdotally thought to be slow moving ambush predators that change their body positions only slightly from day to day. Because they are an arboreal and nocturnal species, their behavior is challenging to study in the field. The behavior of *C. batesii* is not documented in the literature, nor its congeners with evidently similar behaviors with the exception of *Corallus enydris* (Henderson & Winstel, 1992).

This project will analyze behavior of one juvenile *C. batesii* in a lab setting to produce the first behavioral study on this species.

Hypothesis: *Corallus batesii* will be more active during the night.

Due to the knowledge gap on the behavior of the *C. batesii*, the literature used to inform the hypothesis and experimental design are from snakes that are well represented in the literature and share characteristics with *C. batesii*.

For example, the Brown Treesnake (*Boiga irregularis*) is arboreal and nocturnal like *C. batesii*, and we expect that their pattern of activity will be similar. Lardner et al. (2014) observed in the field that the proportion of activity versus inactivity for *B. irregularis* less than an hour after sunset was around .5 and gradually decreased to a proportion of about .3 at sunrise where it drops to less than .1 one hour after sunrise.

A closer relative to *C. batesii, C. enydris*, was observed in the field and it was discovered that *C. enydris* activity began shortly after 1800 h and foraging continued until 2300-2400 h (Henderson & Winstel, 1992). We expect to see this similar pattern with *C. batesii.*

Studying behavior in *C. batesii* may inform decisions about the animals' needs regarding care in captivity. When a snake is stressed, it may spend excessive amounts of time rubbing their snout on the glass, evidently trying to escape to a larger space (J. Mendelson, pers. comm.) and this behavior would be noted separately if it were to occur during this study. Fundamental behavioral studies may also help develop a greater understanding of the environment in which the species evolved in and may help us make more informed decisions regarding protection in the face of endangerment or extinction (Mitrovich et al., 2009; Roe et al., 2010).

Methods

In this paper, the activity budget of one female *C. batesii* is reported; however, data analysis is still ongoing for eleven of her littermates (six females and five males). Their behavior was recorded by two 24-hour 5420IR indoor mini dome cameras with night vision capabilities over a period of 57 days from July 23, 2019 to September 18, 2019. They were kept in individual separate enclosures off-exhibit at Zoo Atlanta. The enclosures were stacked three rows by four columns (Figure 1), and each camera captured two rows (the second row was captured on both cameras). The room lights were turned on at 900 h and turned off at 2130 h everyday; the room did not contain any windows. Zookeepers usually entered the room around 710 h each morning.

We have more than 1300 hours of recorded video per snake and in order to complete data analysis in an appropriate time period, the videos were analyzed in 45-minutes sessions every third hour (eight hours per day) for eight days post-feeding, after which we recorded every other day using the same interval method. In order to account for all hours of the day and night, the interval was adjusted by starting one hour ahead of the last analyzed day. The videos were analyzed using continuous and all-occurrence data collection techniques. The snakes we fed twice during the data collection period (July 23 and August 18). Our data collection started on the first day of a feeding cycle (the day of the first feeding) and continued until the last day of the second feeding cycle (the day before the third feeding).

These videos were analyzed and coded within the event logging software, BORIS (Friard & Gamba, 2016), according to the ethogram we created (Table 1). In total we will have analyzed 219 hours of data per snake; however, at this point in the research, we have analyzed 102 hours corresponding to the first feeding cycle of Snake 10. These data were analyzed as a time budget which indicates what percentage of their time and at which times they exhibited specific behaviors.

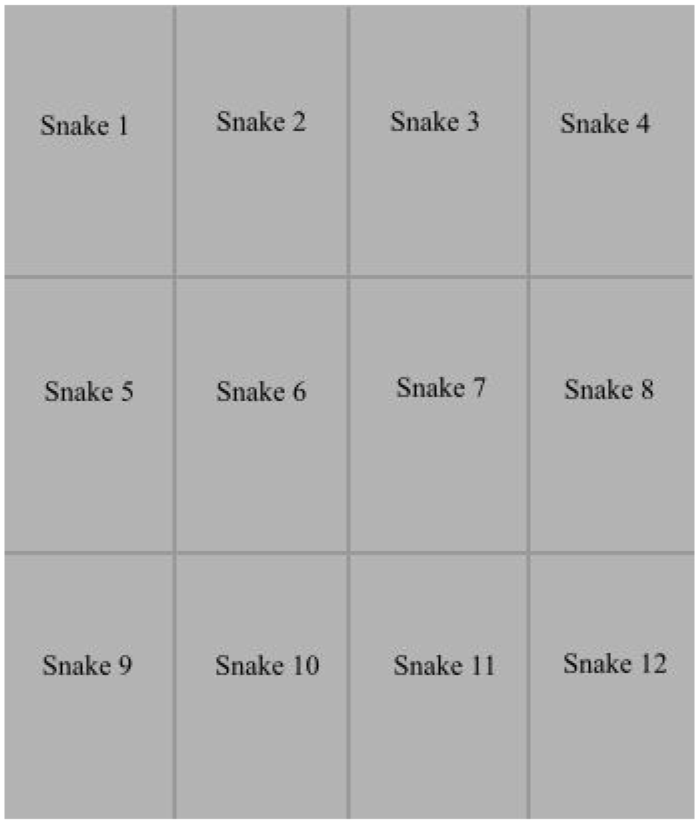

Figure 1) Schematic of *C. batessi* enclosure arrangement

Key	Code	Type	Description
h	Hunting	State event	Subject is stationary and meeting these criteria: 1) 3 or more point S-curve in neck 2) Head is not resting on body
r	Resting	State event	Subject is stationary, in clasping coil, and is not in a predatory posture
m	Movement	State event	Subject's body is in motion
o	Other	State event	Subject is stationary and is performing a behavior that is different from the described behaviors. Subject's head may not be visible, but a stationary position must be confirmed
v	Out of View	State event	Subject is not visible
f	Feeding	Point event	Subject was given a prey item by a staff member
e	Enclosure Lighting	Point event	The status of the enclosure light
d	Room Light	Point event	The status of the room light
s	Enclosure Door	Point event	The status of the door to the subject's enclosure changes
a	Misting	Point event	Subject has been misted by a keeper

Table 1) Ethogram used to record behavior in BORIS software

Results

Preliminary results were found for the activity budget of the first feeding cycle for Snake 10 which seemed to have similar behavior patterns as its littermates. To get a general idea of the daily pattern of how the snake spends its time, the time spent in each behavior (hunting, resting, moving, other: stationary, and out of view) was averaged over all of the coded days and then analyzed using a linear model. The data analyses relied on Microsoft Excel, version 16.34. After testing each of the five behaviors individually according to linear regression analyses, the only behaviors that were significantly predicted according to the time of day were hunting ($p=0.0178$, df=23, t=8.50) and resting (p=0.00337, df=23, t=3.52). The other behaviors, movement (p=0.0828, df=23, t=7.33), other: stationary (p=0.195, df=23, t=7.27), and out of view (p=0.136, df=23, t=8.05), did not vary significantly.

Because the data were coded in 45-minute blocks as opposed to full-hour blocks, there is a small break in the data. To accommodate for this break, the bar graphs more accurately represent the activity budgets as opposed to a more continuous scatter plot. Figure 2 shows resting and hunting together as they were the only behaviors that showed significance relating to time of day. Figures 3 and 4 show movement and other: stationary individually as they relate to time. Out of view was omitted due to insignificance.

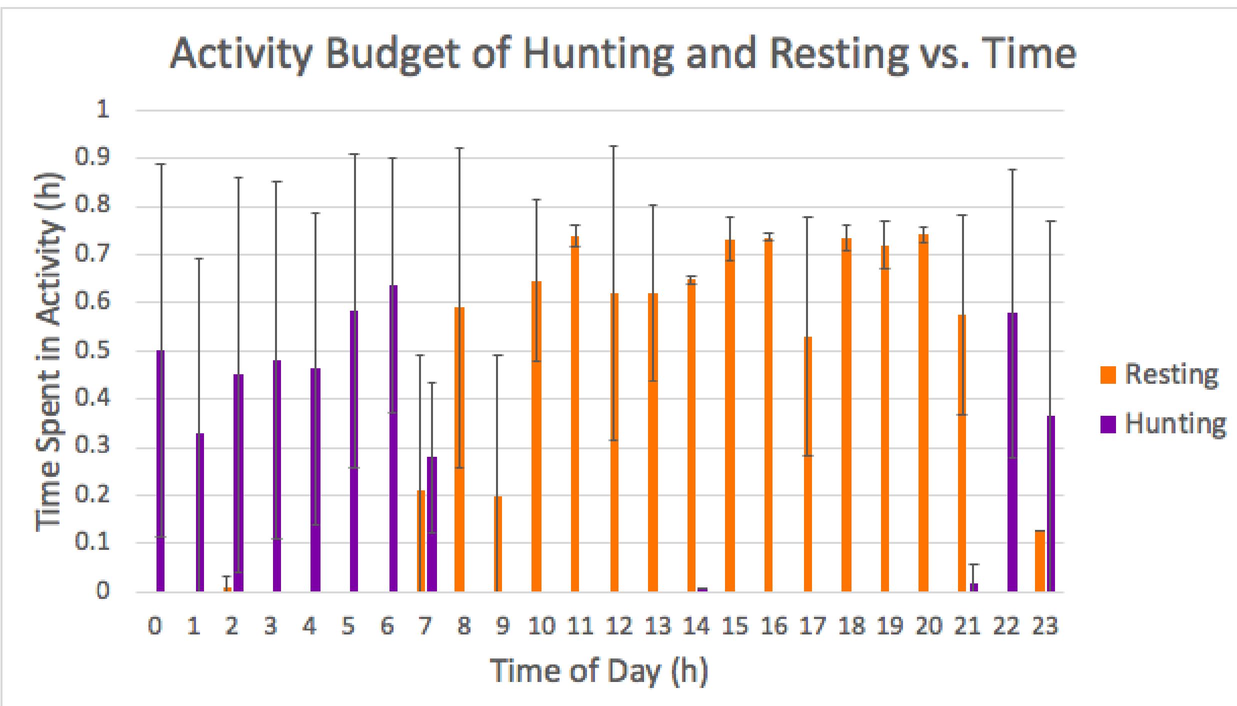

Figure 2) Time of day significantly predicts hunting and resting behavior. This graph shows the amount of time Snake 10 spent in hunting (p=0.0178, df=23, t=8.50) and resting (p=0.00337, df=23, t=3.52) behaviors as a function of time during the first feeding cycle. The values on the x-axis represent the time of day, 0=0:00-0:45, 1=1:00-1:45, etc.

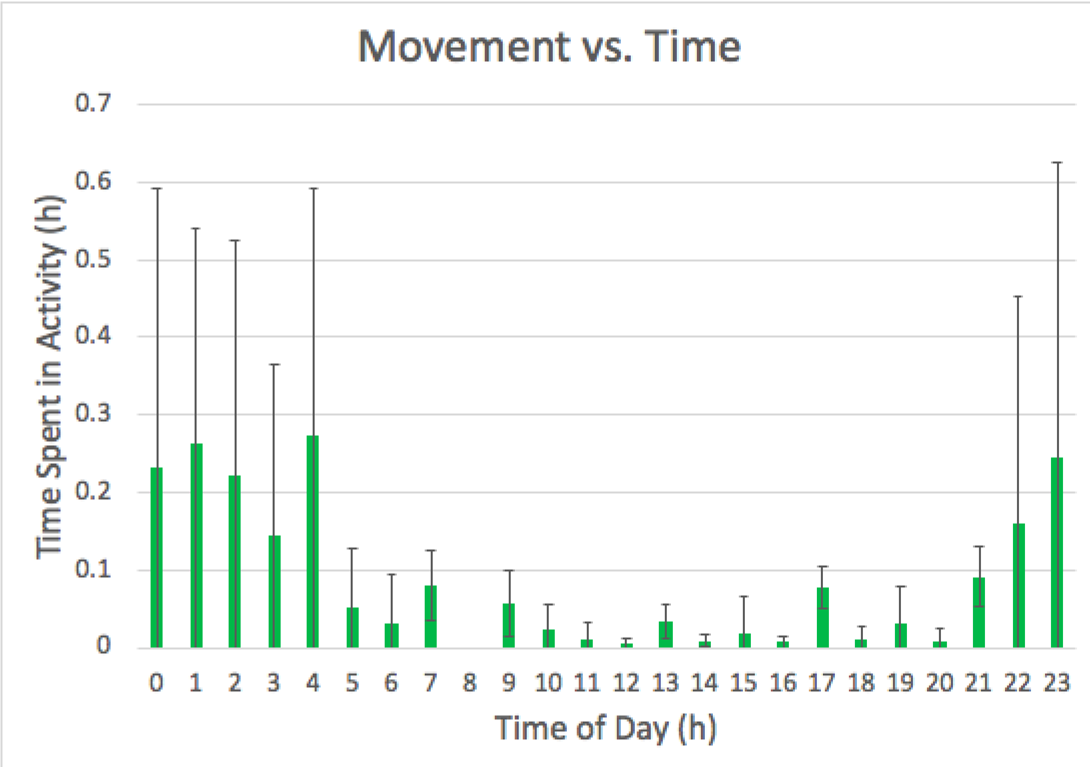

Figure 3) Movement Behavior vs Time. This figure represents the amount of time Snake 10 spent moving (hours) as a function of time (hours) during the first feeding cycle ($p=0.0828$, $df=23$, $t=7.33$). The values on the x-axis represent the time of day, 0=0:00-0:45, 1=1:00-1:45, etc.

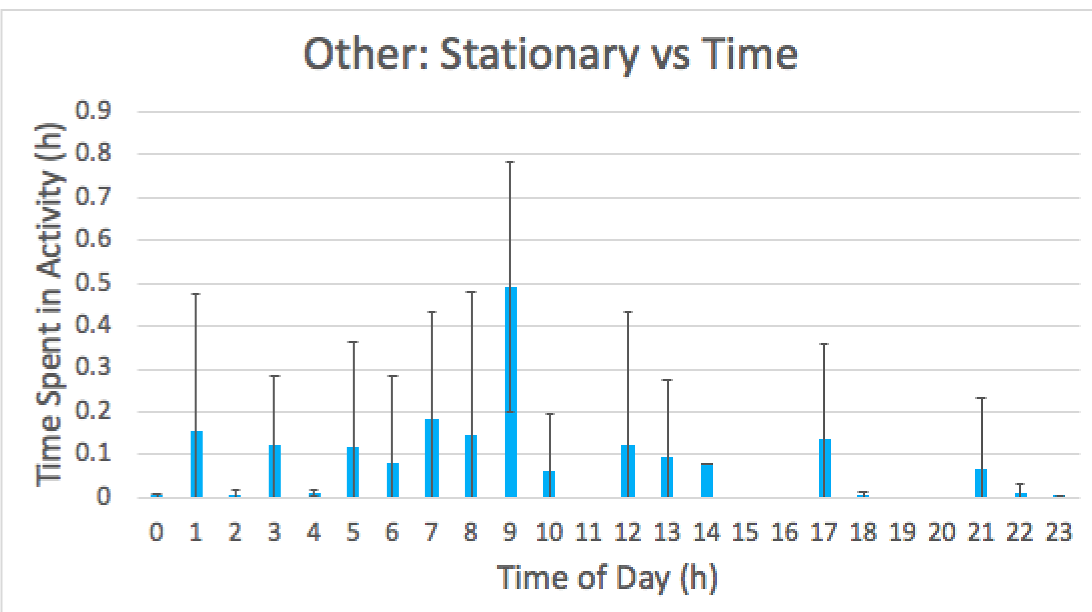

Figure 4) Other: Stationary Behavior vs Time. This graph shows the amount of time Snake 10 spent in other: stationary (hours) as a function of time (hours) during the first feeding cycle ($p=0.195$, $df=23$, $t=7.27$). The values on the x-axis represent the time of day, 0=0:00-0:45, 1=1:00-1:45, etc.

Discussion

The data shows that Snake 10 hunts between 2200 h and 700 h (nighttime) and rests between 800 h and 2100 h (daytime). After testing each behavior individually according to linear regression analyses, the only behaviors that were significantly predicted according to the time of day were hunting ($p=0.0178$, $df=23$, $t=8.50$) in the nighttime and resting ($p=0.00337$, $df=23$, $t=3.52$) in the daytime. With respect to time, hunting and resting have an inverse relationship with time (Figure 2) which is typical of a snake with an ambush hunting strategy (Henderson & Winstel, 1992; Lardener et al., 2014). Therefore, the null hypothesis is rejected and concludes that *C. batesii* is more active at night.

The arboreal, nocturnal Brown Treesnake (*Boiga irregularis*) was observed in the field to be active immediately after sunset with its activity dropping with the sunrise (Lardner et al., 2014). With no exposure to natural light, it was observed that Snake 10 was on a similar schedule as the zookeepers. The snake becomes active within 30 minutes of lights off (2130 h) and ceases activity within 30 minutes of the keepers entering the room in the mornings (710 h).

When a snake is stressed, it may spend excessive amounts of time rubbing their snout on the glass, evidently trying to escape to a larger space (J. Mendelson, pers. comm). This stress-like behavior was not observed in Snake 10 but will be monitored for the remaining eleven littermates.

As data analysis continues, we plan to record the duration of postprandial behaviors (Siers et al., 2018) and test for site fidelity, the tendency to return to a previously occupied location (Reinert, 1984; MacGregor, 1999; Clark, 2006; Reinert et al., 2011; Hartmann et al.,

2003) in addition to coding activity budgets in BORIS. This data will provide a more complete record of *C. batesii* behavior.

Once data analyses are complete, these findings may inform future welfare-based decisions regarding the design and size of enclosures and implementation of props (Ross et al., 2011; Plowman, 2003). In addition to husbandry, collecting basic information like activity budgets of organisms is important when exploring how behaviors are related over an organism's lineage and how that organism interacts with its environment. In the face of endangerment or extinction, behavioral studies are crucial for conservation efforts (Mitrovich et al., 2009; Roe et al., 2010).

The data presented here is limited because only one snake has been represented; however, we expect to see the same trends when data analysis is complete for all twelve snakes. There are also some limitations to behavioral analyses in a lab setting. If analyzed in its natural habitat, we may find variations in its behavior patterns (J. Mendelson, pers. comm). For example, in a lab setting, the snake may exhibit unnatural behaviors like rubbing its nose on the glass of the enclosure which would not be observed in the field. However, a lab setting provides the ability to manipulate the snake's environment in a way that is not possible in the field.

Conclusion

Corallus batesii was observed to hunt at night and rest during the day. The unexpected observation that the snake's activity budget aligned with the zookeepers may inform new studies regarding how quickly the snake's activity budget changes with the manipulation of light schedules.

Future work should include an observational study of *C. batessi* in its natural habitat which should record cycles of the moon, precipitation, sunrise and sunset, ambush and resting locations, and when prey is ingested.

With respect to fundamental behavioral research, when this data analysis is complete it is likely to be important for a deeper understanding of spatial use, foraging methods, and niche for *C. batessi.* It will also inform future welfare-based decisions regarding the design and size of enclosures and implementation of props. Additionally, behavioral studies help us develop a greater understanding of the environment in which the species evolved in and may help us make more informed decisions regarding protection in the face of endangerment or extinction.

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