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Effects of Simulated Moonlight on Activity in the Desert Nightsnake (*Hypsiglena chlorophaea)*

Abstract

The desert nightsnake (*Hypsiglena chlorophaea*) is a small (< 60 cm snout-vent length), cryptic species of snake often associated with desert habitats of the intermountain western United States. This species is both an active and ambush foraging that feeds largely upon small snakes and lizards. For some nocturnal species, such as *H. chlorophaea* lower activity levels in response to a full moon may affect foraging time, as well as reduce the risk of predation. I collected snakes from May to August 2009 in central Washington State, and maintained in captivity using standard husbandry practices. Using moonlight levels gathered at the collection site, I compared the mean numbers of snake movements of 20 adult *H. chlorophaea* during three moonlight trials: new moon (0.05 lux), half moon (0.32 lux), and full moon (2.10 lux). For the 23 hr trial period, simulated moon-up during the half moon and full trials was from 2300 to 0300 hr. Based upon current field data on this species, I predicted that snakes would reduce activity in response to a full moon. During moon-up, there was no difference in the mean number of movements of snakes between the new or half moon trials. However, all snakes made fewer movements during the full moon trial.

Introduction

Several abiotic factors are known to affect the circadian rhythms of vertebrates. Such factors include temperature, precipitation, wind, and moonlight. Effects of moonlight on activity have been extensively studied in both terrestrial mammals and birds. Mammals (Kotler et al. 2004) and some marine birds (Yamamoto et al. 2008) may decrease activity during periods of bright moonlight (e.g., full moon) to avoid detection by predators. In some mammals, bright moonlight may also reduce foraging time (Brown et al. 2001, Kotler et al. 2010).

Moonlight has been shown to influence activity in reptiles as well, in particular snakes. The effects of moonlight on the activity of snakes were first noted by Klauber (1939). More recently, it has been shown that adult prairie rattlesnakes (*Crotalus viridis*) may shift activity in response to moonlight (Clarke et al. 1996). Brown tree snakes (*Boiga irregularis*) are known to reduce activity in response to bright (e.g., full moon) light (Campbell et al. 2008), and fish-eating snakes (*Lycondontomorphus bicolor*) forage less frequently under a full moon (Madsen and Osterkamp 1982). To determine if moonlight affects activity patterns of a nocturnal species of snake, I chose to test the affects of simulated new, half, and full moonlight on activity in the desert nightsnake (*Hypsiglena chlorophaea*).

Hypsiglena chlorophaea is a small (usually < 60 cm in total length), secretive and nocturnal snake distributed from the desert southwest and intermountain western United States northward to south-central British Columbia, Canada (Mulcahy 2008). The northern one-half of the range of *H. chlorophaea* encompasses much of the Pacific Northwest (Nussbaum et al. 1983) where it occurs in a variety of macrohabitats, including shrub-steppe, grasslands, as well as deciduous and coniferous forests (St. John 2002). Historically, *H. chlorophaea* has been considered not just a secretive species, but rare in Washington state. However, recent field work has shown that *H. chlorophaea* is common and abundant in Washington State (Weaver 2008). Additionally, current research on *H. chlorophaea* has shown it to be entirely nocturnal (Weaver and Kardong 2009) and inactive during periods of a full or nearly full moon (Weaver 2010b). Specifically, I

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predicted there would be a difference in movements between trials, and hypothesize a simulated full moon would greatly decrease mean movements similar to what has been observed in the field for *H. chlorophaea* (Weaver 2010b)

Methods

Twenty adult (males > 220 mm SVL, and females > 330 mm SVL, Weaver 2010b) individuals of *Hypsiglena chlorophaea* were collected from May to August 2009 in central Washington State, U.S.A. Of these, 11 were males (Mean SVL = 288 mm; range 240–334 mm), and nine were females (Mean SVL = 364 mm; range 332–502 mm). Snakes were housed individually in 20 x 26 x 51 cm glass aquaria, and maintained on 12 hr:12 hr light cycle year around (lights on at 0830 hr and off at 2030 hr). Temperatures in both the rooms housing the snakes and where experiments were performed were maintained at a range of temperatures in which *H. chlorophaea* are active (18–30 °C). Snakes were fed natural prey items (small lizards) on a weekly basis, with water available at all times. Snakes were maintained in captivity for at least one week before beginning experiments.

I conducted experiments using a square testing arena (1.25 m wide x 0.5 m high) constructed out of compressed fiberglass panel, resting on a metal platform 20 cm above the floor. The floor of the arena was divided into four equal-sized quadrants, each with a small plastic shelter. Overhead 25 watt fluorescent lights provided 12 hrs of simulated daylight, whereas a 20 watt red incandescent bulb enabled observations to be made during the 12 hrs of darkness. To simulate daily circadian rhythms, trials were run for 23 hrs with one hr for change over (from 1700 to 1800 hr) between individual snake trials.

At the beginning of each trial an individual snake was placed into the center of the testing arena, and kept under a small plastic cup. This was lifted and recording commenced. Behaviors were filmed with Panasonic cameras suspended over each arena and recorded with a Panasonic time-lapse VCR. Movements were scored for each time a snake first entered a new quadrant, and recorded for each hr, during the 23 hr trials. Prior to each trial, shelters were washed and dried, and the arena floor was covered with clean, white butcher paper to remove scent marks and prevent trailing by snakes. The trials (new, half, and full) for each snake began at the same time (1830 hr), with individual snakes tested once for each trial.

Moonlight was measured in the field at the collection location for the snakes over the course of four nights for each moon phase (three readings taken per night). Values were measured using a standard 90% white card and a hand held digital light meter (Lodestar model LS1330A, Shenzen Inc., Hong Kong). Values were as follows: new moon (0.05 lux), half moon (0.32 lux), and full moon (2.13 lux). These moonlight values were then simulated in the testing arena using a string of 16, 0.05 watt light bulbs suspended 0.5 meters above the arena. These lights were connected to a rheostat to control light intensity. Using both field and experimental data on peak activity patterns of *H. chlorophaea* (Weaver and Kardong 2009, Weaver 2010b) simulated moon-up lasted five hours, from 2300–0300 hr during half and full moon trials. To avoid an order effect, moonlight phases were randomized for the trials of each individual snake.

While trials were conducted for a full 23 hr period, I compared the mean number of movements (activity) for all snakes during moon-up (2300–0300 hr) for each treatment (new moon, half moon, and full moon) using a randomized complete block design (each moon phase was treated as a block). Trials were analyzed using a one-way ANOVA within SAS. When this test resulted in significance, a Tukey post-hoc test procedure was used. All analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary NC, USA). Means are reported with standard deviation. Significant differences were determined at the level of $P \leq 0.05$.

Results

Snakes became active shortly after lights out at 2030 hr. During the first few hrs of activity snakes investigated shelters, and moved across the open arena floor and along walls. During each of the three trials all snakes ceased movements starting around 0400 hr, and all snakes remained inactive for the remainder of each 23 hr trial.

From 2300-0300 hr (moon-up) the mean number of movements made by snakes between each moon phase trial was significant ($F_{2,19} = 65.19$, $P < 0.0001$). During the new, half, and full moon trials the mean number of moves by snakes were 44.4 ± 5.03, 39.9 ± 3.76, and 22.7 ± 3.17 respec-

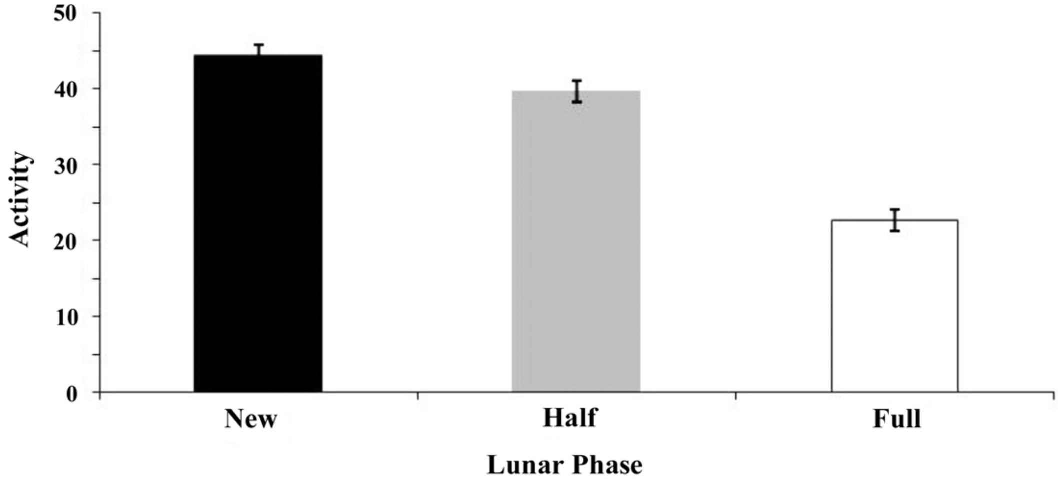

Figure 1. Activity (mean number of movements ± standard deviation) for 20 adult *Hypsiglena chlorophaea* during 2300–0300 hr for new, half, and full moon trials.

tively (Figure 1). A post hoc analysis revealed differences in mean movements between new and half moon trials was not significant ($P = 0.74$), but each differed significantly from the full moon trial ($P < 0.0001$).

Discussion

The results from my experiment show light intensity from a simulated full moon does decrease activity in *H. chlorophaea*. Snakes reduced activity by over 50% during the full moon trials compared to both half moon and new moon trials. Lower activity levels in response a full moon may reduce the possible risk of predation from mammalian or avian predators. Indeed, studies on the foraging behavior of owls have shown that some species have greater success capturing prey during periods of increased moonlight (Clarke 1983). *Hypsiglena chlorophaea* is an active forager (Weaver and Kardong 2009), and this behavior may increase encounter rates with predators. Given the small size of *H. chlorophaea* and its lack of a protective venom system, any nocturnally active predator of snakes could potentially capture and consume this species.

Other species of squamate reptile will reduce foraging behavior during periods of increased moonlight. In the nocturnal, desert inhabiting smooth-scaled gecko (*Teratoscincus scincus*) periods of intense moonlight will reduce the onset and length of foraging activity (Seligmann et al. 2007). However in another species, the Japanese cave gecko (*Goniurosaurus kuroiwae*), which inhabits more forested areas with dense canopy cover, activity is not reduced in response to bright moonlight (Werner et al. 2006). A decrease in foraging behavior has also been shown in *L. bicolor*, where from a new to full moon the percentage of snakes encountered with prey in their stomachs dropped from 45% to 6% (Madsen and Osterkamp 1982). Research on *B. irregularis* reported that, even when prey are available, *B. irregularis* avoided open areas on the ground during a simulated full moon and remained secluded in a simulated canopy microhabitat. (Campbell et al. 2008).

Hypsiglena chlorophaea may also engage in such behavior, choosing to stay hidden under rocks, among rock crevices, or outcrops. During periods of bright moonlight snakes may move between such microhabitats and avoid open areas. Field observations of such movements are lacking for *H. chlorophaea*, whose small body masses currently preclude implantation of transmitters. Unlike *H. chlorophaea*, *B. irregularis* occasionally makes diurnal movements (Tobin et al. 1999). Thus, moonlight may affect activity less so in *B. irregularis*, than in *H. chlorophaea*. In a testing arena, edges may offer a sense of refuge, which has been shown with *C. viridis*. During a simulated full moon, adult (but not juvenile) *C. viridis* moved more often along the edge of the testing arena and avoided open spaces (Clarke et al. 1996).

Beginning with the work of Klauber (1939), and continuing with my research, it is clear that a full moon does indeed affect the activity of squamate reptiles, in particular small nocturnal species, such as *H. chlorophaea*. However, in other examples, species tested may also be diurnally active; as such moonlight may affect activity to a lesser extent. The results of my experiment reveal patterns that may be present in other small, nocturnal species of snakes. Such patterns will only be revealed with additional testing on additional nocturnal species, as well as species whose activity is diurnal or diurnal-nocturnal.

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