DIEL ACTIVITY PATTERNS OF THE LOUISIANA PINE SNAKE (*PITUOPHIS RUTHVENI*) IN EASTERN TEXAS

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Abstract.—This study examined the diel activity patterns of six Louisiana pine snakes in eastern Texas using radio-telemetry. Snakes were monitored for 44 days on two study areas from May to October 1996. Louisiana pine snakes were primarily diurnal with moderate crepuscular activity, spending the night within pocket gopher burrows or inactive on the surface. During daylight hours, snakes spent approximately 59% of their time underground within gopher burrows, burned out/rotten stumps, or nine-banded armadillo (*Dasypus novemcinctus*) burrows. Remaining time was spent on the surface either close to subterranean refuge, or in long distance movements that generally terminated at another pocket gopher burrow system. Long distance movements occurred on 45% of the days snakes were monitored and averaged 163 m/movement. When snakes were active, movements related to ambientair temperature; 82% of these movements occurred between 1000 and 1800 hours. These results confirm that Louisiana pine snakes are diurnal and closely associated with Baird's pocket gophers and their burrow systems, and have provided new insight on the ecology of this rare snake.

The Louisiana pine snake (*Pituophis ruthveni*), first described by Stull (1929), is a large-bodied constrictor of the family Colubridae and until recently was considered one of 15 subspecies of *Pituophis melanoleucus* (see Sweet & Parker 1990; Collins 1991; Crother et al. 2003). The Louisiana pine snake is allopatric to other *Pituophis* and its distribution is primarily restricted to the longleaf pine (*Pinus palustris*) ecosystem of west-central Louisiana and eastern Texas (Conant 1956; Reichling 1995). The longleaf pine ecosystem is perpetuated by frequent fire (Platt et al. 1988; Frost 1993). Louisiana pine snakes are semi-fossorial and are closely associated with Baird's pocket gopher (*Geomys breviceps*) burrow systems (Rudolph & Burgdorf 1997). Baird's pocket gophers are the predominant prey of Louisiana pine snakes and their burrow systems are used for foraging, shelter, escape from frequent fires, and hibernation (Rudolph et al. 1998; 2003).

Many have reported on the apparent rarity of *P. ruthveni*; this can be partly attributed to its semi-fossorial habits and secretive nature (Conant 1956; Young & Vandeventer 1988; Rudolph & Burgdorf 1997). Only 57 records of *P. ruthveni* were available through 1990 (Conant 1956; Jennings & Fritts 1983; Young & Vandeventer 1988; Reichling 1989). As a result, this species is considered to be one of the rarest snakes in North America (Thomas et al. 1991). Extreme rarity has prevented researchers from collecting substantial ecological and natural history data on the species and accounts for the paucity of available literature.

In 1993, the USDA Forest Service Southern Research Station initiated a long term study of home range and habitat use of free ranging Louisiana pine snakes in eastern Texas and west-central Louisiana through the use of radio-telemetry. This portion of the study was conducted from May through October 1996 to elucidate diel activity patterns of this snake in eastern Texas.

STUDY AREAS

Two areas were used to monitor Louisiana pine snakes in eastern Texas. Foxhunter's Hill is a 500 ha longleaf pine savanna located on the Sabine National Forest approximately 25.5 km south of Hemphill, Texas, in Sabine County. The second area, Scrappin' Valley, owned by Temple-Inland Forest Products Corporation, is approximately 29 km south of Hemphill, Texas, in Newton County. The portion of Scrappin' Valley used as the study area is a 450 ha longleaf pine savanna. Characteristics common to both sites are: soils with high sand content; diverse herbaceous flora dominated by little bluestem (*Schizachyrium scoparium*) and bracken fern (*Pteridium aquilinum*); over story dominated by longleaf pine (*Pinus palustris*), sparsely distributed blackjack oak (*Quercus marilandica*) and blue jack oak (*Quercus incana*); and areas of encroachment by sweet gum (*Liquidambar styraciflua*), sassafras (*Sassafras albidum*), and yaupon (*Ilex vomitoria*) as a result of past fire suppression. Foxhunter's Hill possesses moderate topographic relief, average basal area of 9 m^2/ha, and heavy leaf litter accumulation and was burned by prescription in late winter of 1993. Scrappin' Valley has lower topographic relief than Foxhunter's Hill, average basal area of 6 m^2/ha, moderate leaf litter accumulation, and was burned in late winter of 1995. Generally, Scrappin' Valley was burned annually while Foxhunter's Hill was burned every 3-5 years, resulting in differential leaf litter accumulation in the two areas.

MATERIALS AND METHODS

Transmitter implantation.—Louisiana pine snakes were captured on the study areas by hand or in drift fence/funnel traps. Temperature sensitive transmitters (Holohil Systems Ltd., SI-2T) 29mm long and 10 mm in diameter with 28 cm whip antennae were implanted subcutaneously following the general procedure of Weatherhead & Anderka (1984). Transmitter life-span was approximately 18 months and maximum transmission range was approximately 1200 m.

Radio-telemetry/data collection.—Snakes were located early in the morning before they became active and emerged from subterranean shelter. A Trimble GPS Professional unit and data logger was used to record each snake's location. Air temperature at the snake's location was measured with a mercury thermometer 0.5 m above the ground in the shade. Substrate temperature was recorded in one of two ways: if the snake was aboveground, the thermometer was placed on the substrate as close as possible to the snake without disturbing it; if below ground, the thermometer was inserted approximately 5 cm into the soil. Snake body temperature was determined by comparison of transmitter pulse rate with a calibration curve for each transmitter.

Throughout the day until sunset, transmitter pulse counts and air temperatures were recorded at 30-45 minute intervals. When the pulse count of a transmitter changed by becoming much slower or faster, indicating a temperature change of the implanted transmitter, the snake was relocated to determine if snake activity had occurred. Six snakes, three on Foxhunter's Hill, and three on Scrappin' Valley were monitored from dawn to dusk for a total of 44 snake days. Movements were recorded and calculated only if an individual moved more than 10 m from its previous location on a given day (Slip & Shine 1988). Movements on six additional days were recorded during the course of other data collection and were also available. Movement distances were calculated through the use of Trimble GPS Pathfinder Office software (Trimble Mapping and GIS Systems Division, Sunnyvale, CA).

Periodic night checks were conducted by locating snakes at sunset and again at midnight and before sunrise to determine if the snakes were active nocturnally. Additional data regarding movement and choice of underground refugia were collected from these and other snakes in addition to the 44 snake monitoring days.

Habitat measurements were taken at each snake relocation point as required for various aspects of research on *P. ruthveni*. Additional habitat measurements were taken at 100 stratified random points determined by overlaying a grid on the overall study site and using the intersections of the grid lines as the random points. The only habitat measurement relevant to this study was the number of burrows counted within an 11.2 m radius (0.04 ha) of each habitat point. *Geomys breviceps* "burrows" were counted as the number of visible push-up mounds and all other burrows were enumerated by the number of actual openings at or near the soil surface.

Data analysis.—Distance moved per snake each day was tested by a Mann-Whitney U-test. Chi-square contingency tests were used to evaluate the time each snake utilized above ground and below ground environments, movement frequency, and refuge/shelter types used. Frequency of movements during 12 two-hour time periods were evaluated by Chi-square contingency tests and all statistical analyses were performed at an alpha level of 0.05.

Results

Six *P. ruthveni* (5 F, 1 M) were monitored during all or most of a total of 44 snake days between July and October, 1996. During the 44 snake days of monitoring, individual snakes were located at the surface between sunrise and sunset for 145 hrs of a total of 354 hrs (41%). The remainder of their time was spent underground in *G. breviceps* burrows, nine-banded armadillo burrows, and decayed or burned stump holes and associated root channels.

In order to determine nocturnal behavior, the six *P. ruthveni* were monitored at approximately sunset, midnight, and sunrise for a total of 20 snake days during July and August. With one exception, all snakes were located below ground in *G. breviceps* burrows each night (n = 17). The exception, a female, was located on the surface beneath dense herbaceous vegetation at sunset on three separate days and remained in that location until the next morning. One of these instances was during pre-ecdysis. For the 44 snake days when extensive monitoring occurred, snakes were assumed to have spent the previous night in *G. breviceps* burrows, based on early morning detections, a total of 29 times. These same snakes were assumed to have spent the succeeding night in subterranean retreats in 38 instances (35 in *G. breviceps* burrows, three in *D. novemcintus* burrows) based on detections at dusk. Data are not available for the remaining 21 nights.

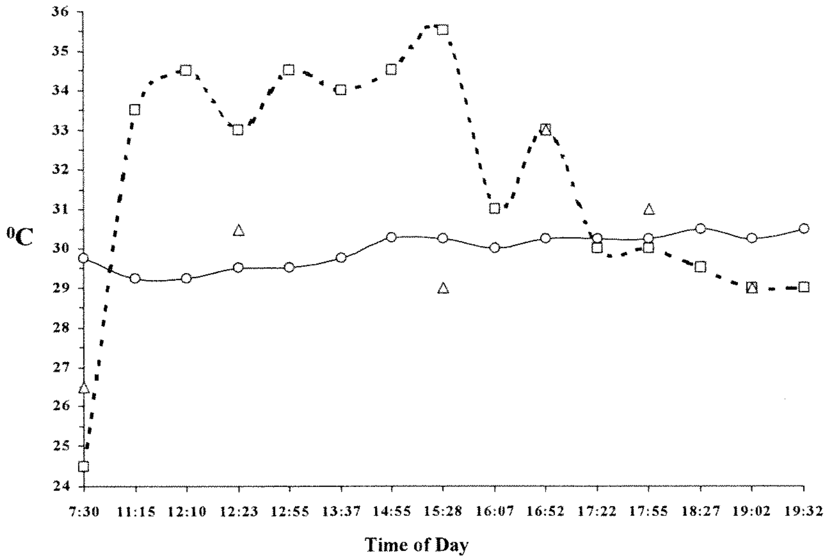

Figure 1. Body temperature (open circles), air temperature (open squares), and substrate temperature (open triangles) for a Louisiana pine snake (*Pituophis ruthveni*) spending daylight hours underground in a Baird's pocket gopher (*Geomys breviceps*) burrow. Adult female 143 on 14 July 1996.

Pituophis ruthveni monitored for daily activity during this study evinced three general daily activity patterns. In 17 cases, snakes remained in *G. breviceps* burrow systems for the entire daily tracking period (Fig. 1). All six snakes except one female from Scrappin' Valley spent at least one entire day in a *G. breviceps* burrow. Conversely, three individuals spent an entire day on the surface. Two of these individuals moved significant distances (225 m and 59 m), and the third was in pre-ecdysis condition with clouded eyes.

In 24 cases various combinations of time were spent on the surface and below ground. These cases were usually associated with substantial surface movement (19 of 24), usually culminating with entrance into another underground refuge (22 of 24) (Fig. 2). Of these 24 snake days, 12 involved snakes that were on the surface when first located in the morning and 12 were in *G. breviceps* burrow systems from which they subsequently emerged. It is unclear if the snakes initially located on the surface had emerged from underground refugia early or had spent the night on the surface, although sampling for nocturnal activity suggests the former in most instances.

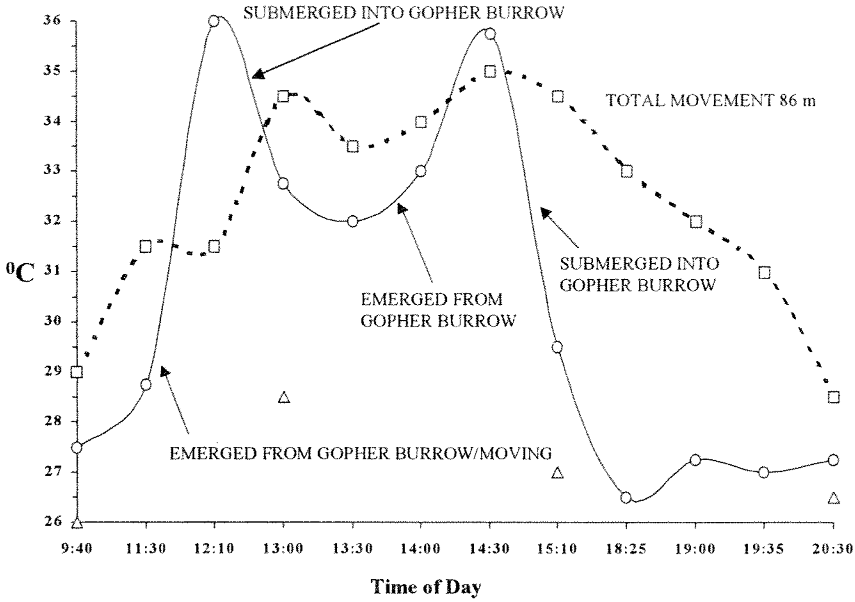

Figure 2. Body temperature (open circles), air temperature (open squares), and substrate temperature (open triangles) for a Louisiana pine snake (*Pituophis ruthveni*) spending portions of a day underground in a Baird's pocket gopher (*Geomys breviceps*) burrow and portions above ground. Adult female 118 on 03 August 1996.

On the 27 snake days in which at least a portion of the day was spent on the surface plus six additional snake days for which movement distances are available, seven snakes remained in the same location, exhibiting only minor movements of <10 m throughout the day. One individual moved 72 m from its initial location, but returned to its initial location by dusk. In 25 instances snakes moved substantial distances (>10 m) during the day and were located an average of 163 m (range 11-625 m) from their initial location. Movements occurred from shortly after sunrise until dusk with the majority (82%) between 10:00 and 18:00 hours (Fig. 3). Overall, snakes moved a substantial distance on 20 of 44 days monitored (45.5%). There was a significant difference in frequency of movement between Scrappin' Valley and Foxhunter's Hill snakes ($\chi 2 = 9.99$, $df = 1$, $P < 0.005$) with the Scrappin' Valley snakes moving more frequently (Table 1). Daily movement distances were calculated by summing straight line measurements between consecutive locations and should be interpreted as an underestimation since snakes rarely travel in a straight line (Secor 1994). On days when movement occurred, snakes at Scrappin' Valley (Table 1) moved greater distances, ($\bar{x} = 189$ m, $n = 19$) than did those on Foxhunter's Hill ($\bar{x}$

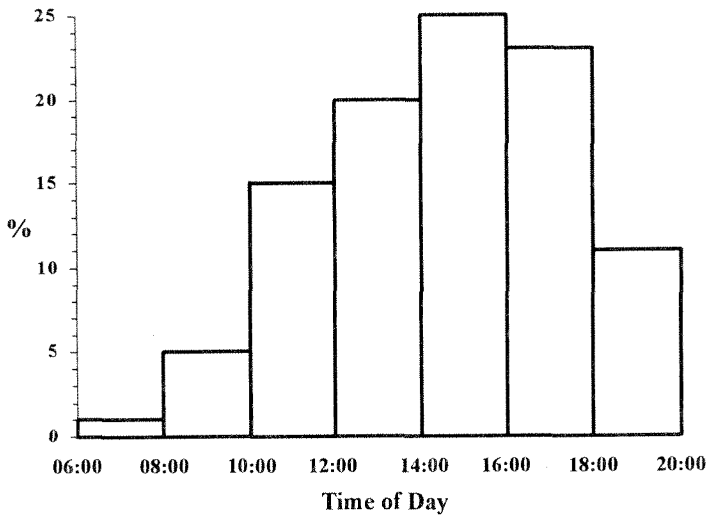

Figure 3. Frequency distribution (%) of movements by six Louisiana pine snakes (*Pituophis ruthveni*) relative to time of day. Data for 12 May - 27 October 1996.

= 91 m, n = 7); this difference was significant (U = 40.5, df = 26, $P < 0.05$).

Pine snake use of underground refugia was recorded on 44 days during which daily activity patterns were monitored and on other days when snakes were located for home range computation. Snakes used *G. breviceps* burrows (80.9%), decayed or burned stumps (15.4%), or *D. novemcintus* burrows (3.7%) as underground refugia. Based on habitat data collected at random points (Table 2), Scrappin' Valley had significantly higher densities of *G. breviceps* burrows (χ^2 = 193.9, df = 1, $P < 0.005$) and other types of retreats (χ^2 = 10.2, df = 1, $P < 0.005$) than Foxhunter's Hill. Compared to snakes at Foxhunter's Hill, snakes at Scrappin' Valley used underground retreats other than pocket gopher burrows more frequently ($\chi 2$ = 29.31, df = 1, $P < 0.001$).

The percent of time an individual utilized underground environments on days snakes were monitored was determined through visual observations and making inferences from temperature relationships based on the snakes' body temperature compared to air and substrate temperatures. Snakes at Scrappin' Valley (Table 1) spent a significantly lower proportion of daylight hours underground (45%) compared to snakes at Foxhunter's Hill (74%) (χ^2 =19.96, df = 1, $P<0.05$).

Table 1. Distance moved, movement frequency, and time spent below ground (% time sunrise to sunset) for six Louisiana pine snakes (*Pituophis ruthveni*) at Scrappin' Valley and Foxhunter's Hill in eastern Texas.

Study Area	Range of movement (m)	Mean distance moved per day (m)	Movement frequency (%)	% Time below ground
Scrappin Valley	12-625	189±35	68	45
Foxhunter's Hill	11-184	91±22	24	74
Combined	11-625	163±32	46	59

Table 2. Indices of burrow abundance at snake relocation points and random points (0.04 ha plot) (Scrappin' Valley and Foxhunter's Hill in eastern Texas).

Study Area	No. of gopher burrows at snake relocation points	No. of gopher burrows at random points	No. of burrows at snake relocation points	No. of burrows at random points
Scrappin Valley	7.74	2.52	1.28	0.70
Foxhunter's Hill	8.08	0.64	0.62	0.37

During the May through October period when *P. ruthveni* temperatures were monitored, subterranean retreats, primarily *G. breviceps* burrows, provided a refuge from extreme temperatures. *Pituophis ruthveni* emerged from subterranean retreats at body temperatures ranging from 19 to 29°C. The lower temperatures were recorded in May and October, and the higher temperatures were presumably associated with snakes that were re-emerging within a day or had undergone a period of basking at the burrow entrance prior to actual emergence. Body temperatures of snakes in subterranean retreats were generally within 2°C of soil temperatures at a depth of 5 cm which ranged between 20.75 and 32.5°C.

Body temperatures of snakes present on the surface ranged from 20 to 36.75°C. However, snakes frequently maintained body temperatures between 25.5 and 34.5°C by basking, even when air temperatures were as low as 22°C. Air temperatures never exceeded 35.5°C during monitoring periods, but *P. ruthveni* frequently moved into subterranean retreats as air temperatures approached 35°C.

Discussion

Surface activity of *P. ruthveni* was determined to be essentially diurnal. Individuals were typically located in subterranean retreats, generally those of *G. breviceps,* at night. Snakes located above ground at night were inactive and sheltered under low vegetation. Diurnally, *P. ruthveni* were located above ground 41% of the time, and all recorded movements occurred during daytime. Diurnal activity is typical of *Pituophis* sp. with the exception of populations located in desert environments where diurnal activity is severely limited by high temperatures (Gibbons & Semlitsch 1987). *Pituophis ruthveni* also spent a substantial portion of daylight hours underground (59%), generally in burrows of *G. breviceps*. The close association of *P. ruthveni* with *G. breviceps* burrows provides substantial opportunity to avoid extreme air temperatures.

The close association with the burrows of *G. breviceps* is consistent with other observations of the ecology of *P. ruthveni*. *Geomys breviceps* is the primary prey of *P. ruthveni* (Rudolph et al. 2003), and decline or loss of *G. breviceps* populations, generally resulting from alteration of the fire regime, is hypothesized to be an important cause of population declines (Rudolph & Burgdorf 1997). In addition, *G. breviceps* burrows are the only documented hibernaculum sites, and are used for escape from predators and fire (Rudolph et al. 1998).

Pituophis ruthveni were relatively immobile (i.e., moved < 10 m) on 54.5% of days monitored. This is consistent with a figure of 43% for northern pine snakes, *P. melanoleucus melanoleucus*, in New Jersey (Burger & Zappalorti 1989). Relative inactivity has been hypothesized to be a critical component of the thermal ecology of reptiles (Gans & Dawson 1976). This may be the case with *P. ruthveni* because remaining immobile near a subterranean retreat provides immediate access to two divergent thermal regimes. Huey (1982) also suggested that inactivity conserves energy and reduces the risk of predation. In a generally more mobile and active species, *Coluber constrictor*, Plummer & Congdon (1994) found that 90% of inactivity was associated with ecdysis. In *P. ruthveni*, only 13% of inactive days were associated with ecdysis, suggesting that the previously mentioned factors may be involved in the relative inactivity of this species.

Pituophis ruthveni moved an average of 163 m/d on those days when substantial movements were undertaken. This is similar to the findings of Fitch & Shirer (1971) for *P. catenifer* in Kansas (142 m/d) and considerably greater than Parker & Brown (1980) found for *P. catenifer deserticola* in Utah (71 m/d). Long-distance movements in *P. ruthveni* generally involved movement from one *G. breviceps* burrow system to another and consequently reflect the dispersed distribution of these burrow systems.

Pituophis ruthveni, during this and associated studies were found to move very little while underground in *G. breviceps* burrows, typically remaining near the point of entrance in the relatively shallow foraging tunnels. This suggests that *P. ruthveni* behave as sit-and-wait predators when hunting pocket gophers, rather than actively searching within the burrow system. *Geomys breviceps* maintain an intricate burrow complex that can reach 180 m in length (Schmidly 1983), and they can rapidly construct an earthen plug effectively limiting movement by *P. ruthveni* (Rudolph et al. 2003). These observations suggest that a sit-and-wait strategy combined with a brief pursuit may be the most effective strategy to capture *G. breviceps*.

Pituophis ruthveni behavior differed significantly, based on three criteria, between the Scrappin' Valley and Foxhunter's Hill study sites. Snakes at Scrappin' Valley moved more frequently, moved greater distances, and spent less time underground compared to snakes at Foxhunter's Hill. The Scrappin' Valley site was also characterized by a greater density of both *G. breviceps* burrows and other types of retreats compared to the Foxhunter's Hill site. It is possible that the greater availability of subterranean retreats at Scrappin' Valley resulted in fewer restrictions on above ground activity by *P. ruthveni*. The greater availability of *G. breviceps* burrows and other subterranean retreats (primarily burned stump and root channels) is presumably related to the more frequent prescribed fire regime at the Scrappin' Valley site.

The use of subterranean retreats during the active period of the year provided *P. ruthveni* with predictable escape from excessively high air temperatures. Conversely, snakes also had direct access to basking opportunities on the surface that allowed the snakes to maintain a higher body temperature during substantial periods. This general pattern is similar to the results of Himes et al. (2002) for this species in northern Louisiana.

The diel activity budget of *P. ruthveni* reveals a species that is diurnal and semifossorial as is generally typical of other members of the genus in the United States (Fitch & Shirer 1971; Parker & Brown 1980; Sweet & Parker 1990). The importance of burrows of Baird's pocket gophers when combined with previous data and observations (Rudolph &

Burgdorf 1997; Rudolph et al. 1998; 2003) supports the hypothesis that *P. ruthveni* is dependent on *G. breviceps* and ultimately on a frequent fire regime that maintains the herbaceous vegetation that supports *G. breviceps* populations.

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