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Winter Movements of Louisiana Pine Snakes (*Pituophis ruthveni*) in Texas and Louisiana

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Abstract - Despite concerns that the Louisiana Pine Snake (*Pituophis ruthveni*) has been extirpated from large portions of its historic range, only a limited number of studies on their movement patterns have been published. Winter movement patterns are of particular interest since it has been hypothesized that impacts of management practices would be reduced during the winter. Using radiotelemetry, we determined winter movement patterns of Louisiana Pine Snakes (11 males, 8 females) in 5 study areas (2 in Louisiana and 3 in Texas). Movements during winter (November–February) were greatly curtailed compared to the remainder of the year; however, snakes occasionally undertook substantial movements. Relocations were typically within the snake's previous active-season home range, and movements were more frequent in the early portion of winter. All hibernation sites were within Baird's Pocket Gopher (*Geomys breviceps*) burrow systems at depths ranging from 13–25 cm. Louisiana Pine Snakes did not use communal hibernacula, nor did individual snakes return to previously used sites in successive years.

Introduction

Snakes of the genus *Pituophis* (Holbrook) are large, terrestrial constrictors that feed primarily on mammals in open habitats (Rodriguez-Robles 2002, Sweet and Parker 1991), and are widely distributed in North America (Sweet and Parker 1991). *Pituophis ruthveni* Stull (Louisiana Pine Snake) is a narrowly distributed species found in eastern Texas and west-central Louisiana (Reichling 1995, Rudolph et al. 2006, Sweet and Parker 1991). The species is thought to have been extirpated from large portions of its historical range, and extant populations are currently known from a limited number of small and fragmented localities (Reichling 1995, Rudolph et al. 2006). The Louisiana Pine Snake is listed as threatened by the Texas Parks and Wildlife Department and is classified by the US Fish and Wildlife Service (USFWS) as a candidate species for listing as threatened or endangered under the Endangered Species Act (USFWS 2012).

Few studies on the ecology of the Louisiana Pine Snake have been published. Recent ecological research has demonstrated that the Louisiana Pine Snake is a

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diurnal species (Ealy et al. 2004) primarily associated with open pine forests on sandy soils with abundant herbaceous vegetation (Himes et al. 2006a, Rudolph and Burgdorf 1997). Within the snake's historical range, this habitat is maintained by frequent fire (Conner et al. 2001, Frost 1993). The Louisiana Pine Snake preys primarily on *Geomys breviceps* Baird (Baird's Pocket Gopher; Rudolph et al. 2002, 2012) and makes extensive use of pocket gopher burrow systems for shelter, hibernation, and to escape from fires (Rudolph and Burgdorf 1997; Rudolph et al. 1998, 2007). The reduction in pocket gopher populations, resulting from the loss of herbaceous vegetation density and diversity due to fire suppression, is thought to be a factor in the decline of the Louisiana Pine Snake (Rudolph and Burgdorf 1997, Rudolph et al. 2006).

Louisiana Pine Snakes are most active during March–May and September–November, possibly because above-ground temperatures are optimum for movement (Himes et al. 2006a, b). For this reason, land managers have proposed to conduct forestry activities, such as timber harvest, during the winter months when Louisiana Pine Snakes are thought to be dormant Himes et al. 2006a). These management practices should mitigate incidental take of Louisiana Pine Snakes; however, knowledge of winter activity patterns of Louisiana Pine Snakes is restricted to populations in Bienville Parish, LA, where Himes et al. (2006a) found that snakes remained underground and inactive during the winter months (December–February).

Our objective was to augment our knowledge of winter movement patterns of Louisiana Pine Snakes throughout their currently known range. Better understanding of winter movement patterns should aid land managers in determining the time of year when Louisiana Pine Snakes are least likely to be adversely affected by forestry practices.

Materials and Methods

We captured snakes (11 males, 8 females) in 5 study areas: private land in Bienville Parish, LA (Himes et al. 2006a); Ft. Polk Military Reservation in Louisiana; privately owned Scrappin' Valley in Newton County, TX; Sabine National Forest in Sabine County, TX (Ealy et al. 2004); and Angelina National Forest in Angelina and Jasper counties, TX. All sites had soils with a high sand content, a diverse herbaceous flora dominated by *Schizacharium scoparium* (Michx.) Nash (Little Bluestem) and *Pteridium aquilinum* (L.) Kuhn (Bracken Fern), and an overstory dominated by pines, primarily *Pinus palustris* P. Mill. (Longleaf Pine). All sites have gently rolling topography intersected by intermittent and small permanent streams.

We captured the snakes by hand (n = 6) or with drift fence and funnel trap arrays (n = 13; Burgdorf et al. 2005) between 1993 and 1997. Treatment of captured individuals was as follows: for each snake we determined weight to the nearest gram, snout–vent length (SVL) to the nearest centimeter, and sex by probing for hemipenes (Schaefer 1934). We then implanted all snakes in Bienville Parish with Holohil SI-2T transmitters (44 x 10 mm, 29-cm whip antennae, weight 12 g; Holohil Systems Ltd., Carp, ON, Canada) intraperitoneally following Reinart and Cundall (1982), except for 1 juvenile snake, in which we similarly implanted a

2.5-g transmitter (constructed by P. Blackburn, Stephen F. Austin State University, Nacogdoches, TX). We implanted the remaining snakes subcutaneously following the general procedures of Weatherhead and Anderka (1984) with Holohil SI-2T transmitters. We anesthetized snakes using ketamine hydrochloride or halothane. Transmitters weighed <2.5% of snake body mass. Transmitter life span was approximately 18–24 months, and maximum transmission range was approximately 1200 m. After surgery, we kept snakes in the laboratory and monitored them for at least 5 days, then released them at their capture location. We replaced transmitters as necessary, generally every 18 months.

We relocated snakes using either an H antenna or a 3-element Yagi antenna and a R2100 receiver (Advanced Telemetry Systems, Inc. , Isanti, MN). Generally, we tracked snakes less often and more irregularly during winter (November–February; mean = 2.7 relocations/snake/month) than during active season months (March–October; mean = 6.5 relocations/snake/month).

We used a Trimble GPS Professional™ unit to record relocation site coordinates (any location of a telemetered snake after surgery and subsequent release) and corrected the values using post-processed differential correction. Snakes were not disturbed during this portion of data collection. We considered snake locations ≥5 m from a previous location as movement, and collected new coordinates (Himes et al. 2006a).

We excavated seven of 19 Louisiana Pine Snakes from gopher burrows during winter to determine the distance (cm) of the snake from the presumed entrance and the depth (cm) of the snake within the burrow system. For a complete description of this process, see Rudolph et al. 2007.

We calculated monthly movement frequencies by dividing the total number of movements by the total number of relocations for all snakes, across all years. We divided monthly frequencies into seasons (active season: n = 8 months; winter: n = 4 months). We compared seasonal movement frequencies using a 2-sample t-test at an alpha level of 0.05.

We chose each snake's winter dormancy location based on the amount of time the snake spent in its winter locations, attempting to choose the single point that best represented the site of winter dormancy. We calculated the distance from the previous year's winter dormancy location using ArcGIS version 9.3 (Environmental Systems Research Institute, Redlands, CA).

To assess whether snakes were spatially distributed differently between winter and the active season, we measured the distances of winter dormancy locations from the edge of the active-season (March–October) 100% minimum convex polygon (MCP) home ranges (J.B. Pierce, unpubl. data). We calculated home ranges with Home Range Tools for ArcGIS (Rodgers et al. 2007) in ArcGIS version 9.3.

Results

During 1993–1998, we tracked 19 snakes for at least one consecutive active season and winter season. The number of winters tracked (range = 1–4) varied across individuals, resulting in a total of 37 snake winters (Table 1). We located snakes during winter on a total of 283 occasions, of which only 89 were unique locations because individuals often remained in the same location for one or more subsequent relocations and occasionally returned to previously used locations.

All winter locations were within Baird's Pocket Gopher burrow systems. Rudolph and colleagues (2007) presented data on Louisiana Pine Snake hibernacula using the same snakes as we followed in this study. They excavated 7 snakes from burrows at depths ranging from 13–25 cm (mean = 19.0 ± 4.9 cm; Rudolph et al. 2007). These snakes were <1 m from the presumed point of entrance into the burrow system (Rudolph et al. 2007). Winter refuge placement of all snakes was similar to the positions occupied by snakes at other seasons when using pocket gopher burrows for foraging and refuge (Rudolph et al. 2007).

Because snakes were tracked less often during winter than the other seasons, we might have underestimated the amount of winter movement if snakes moved undetected but returned to previously used sites in the time between our tracking efforts. Snake movement frequencies (mean = 24.0%) were significantly lower during winter when compared to the other seasons (mean = 66.2%; $t = 6.93$, df = 10, $P = 0.002$; Fig. 1). Movement frequencies began to decline in September, remaining at ≈59% through October. In November, movement frequencies drastically declined and remained low (<37%) until March, at which point snakes returned to a 58% movement frequency (Fig. 1).

Table 1. Snout–vent length (SVL; cm), study site (ANF = Angelina National Forest, BP = Bienville Parish, FP = Ft. Polk, PR = Peason Ridge, SNF = Sabine National Forest, SV = Scrappin' Valley), and number of relocations for each winter Louisiana Pine Snakes were tracked. Dashes (-) indicate years that snakes were not tracked. Asterisks (*) indicate snakes used in Himes et al. 2006a.

Snake ID #	SVL	Study site	1993–1994	1994–1995	1995–1996	1996–1997	1997–1998
Male 1	136	ANF	14	9	7	2	-
Male 2	123	ANF	-	-	7	2	4
Male 3	132	SV	-	-	3	-	-
Male 4	131	SV	-	-	-	4	-
Male 5	105	FP	-	-	-	11	7
Male 6	115	FP	2	-	-	-	-
Male 7*	112	BP	-	-	7	30	9
Male 8*	135	BP	-	-	6	10	-
Male 9	105	BP	-	-	7	9	-
Male 10*	116	BP	-	-	-	-	10
Male 11	113	FP	-	-	-	-	8
Female 1	130	SV	-	-	-	3	-
Female 2	131	SV	-	-	3	-	-
Female 3	115	SNF	-	-	6	2	-
Female 4	130	SNF	14	4	6	1	-
Female 5	116	SNF	-	9	3	2	-
Female 6	113	FP	-	-	-	10	-
Female 7*	110	BP	-	-	7	30	6
Female 8*	80	BP	-	-	-	-	9

Although movements were greatly curtailed compared to the remainder of the year, snakes occasionally undertook substantial movements during winter (n = 50, range = 5 to 841 m, mean = 103.2 m). We recorded data for 12 successive winter dormancy locations of individual snakes, which ranged from 112 to 1406 m (mean = 533.5 ± 127.6 SE) from the previous year's winter dormancy location. We did not detect any individuals using the same winter dormancy location in successive years, or multiple individuals using the same dormancy location simultaneously.

Relocations were typically within the previous active-season MCP home range (68 of 89 unique locations). The 21 unique locations outside of the MCP ranged from 2–118 m away from the respective home range (mean = 45.9 ± 8.1 SE). We did not develop minimum convex polygons to determine winter home ranges because sample sizes of unique winter relocations (mean = 4.7) precluded statistical analysis of winter home-range use.

A male individual from the Angelina National Forest displayed the most extreme winter movement among all snakes. During the winter of 1993–1994, it was relocated 14 times in the same winter refuge (Point A; Fig. 2). The moves before and after the winter season were relatively short (43 and 35 m, respectively; Fig. 2). The following winter (1994–1995), the snake was relocated 9 times (7 unique locations), during which it moved over 1000 m. Two relocations accounted for most of this movement (Fig. 2). The snake was returned to the lab on 31 January 1995 for transmitter replacement. During the winter of 1995–1996, we relocated the snake 7 times (4 unique locations). It moved 133 m in mid-November to an area where it remained until late February 1996, at which time it moved 841 m to the west, beginning its post-winter movements (Fig. 2).

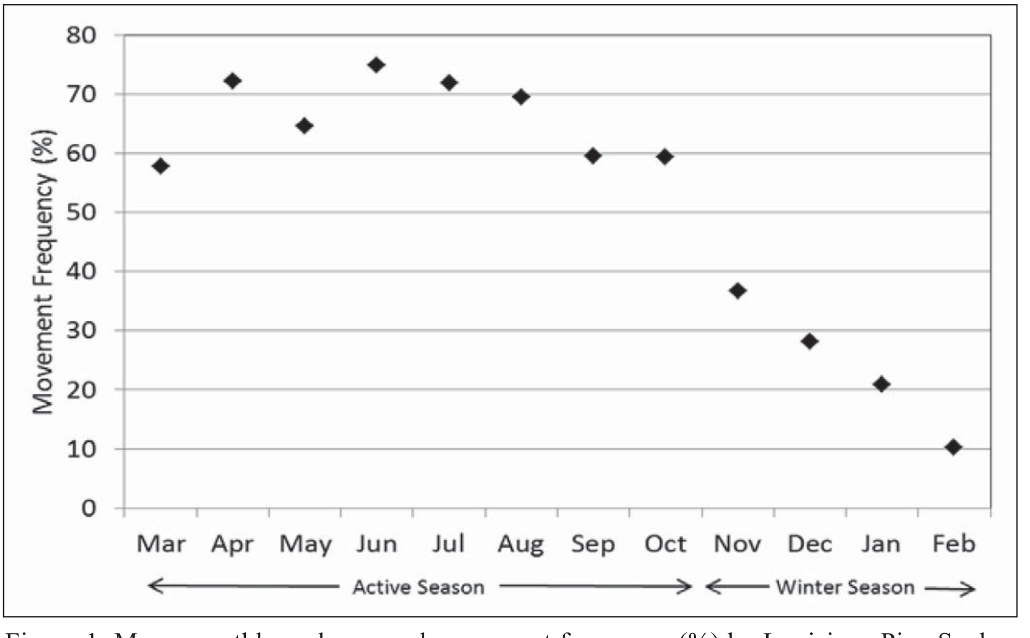

Figure 1. Mean monthly and seasonal movement frequency (%) by Louisiana Pine Snakes in Texas and Louisiana, 1993–1997.

Discussion

During the colder months (November–February), Louisiana Pine Snakes greatly curtailed their movements and remained in the burrows of pocket gophers at relatively shallow depths (13–25 cm; Rudolph et al. 2007). A tendency for movements to be more frequent in early winter was observed, suggesting that the behavioral and physiological transition towards less activity is a gradual process. Presumably, Louisiana Pine Snakes also curtailed their feeding activities during the colder months, based on the reduced movement between burrow systems, and their presence in inactive portions of pocket gopher burrow systems (Rudolph et al. 2007). We did not detect Louisiana Pine Snakes using the same pocket gopher burrow system for winter dormancy in successive years. The mean distance from the site of previous year's winter dormancy location was <600 m. Louisiana Pine Snakes did not make directed movements to wintering sites at the end of the fall, but simply curtailed movements at the burrow system occupied at the end of the fall. This strategy may decrease the frequency of relatively long surface moves, in turn potentially reducing predation risk during a return to a permanent or traditional location.

There are some differences between our findings and those of Himes et al. (2006a) regarding winter activity patterns of Louisiana Pine Snakes. While Himes et al. (2006a) found that Louisiana Pine Snakes are most active during

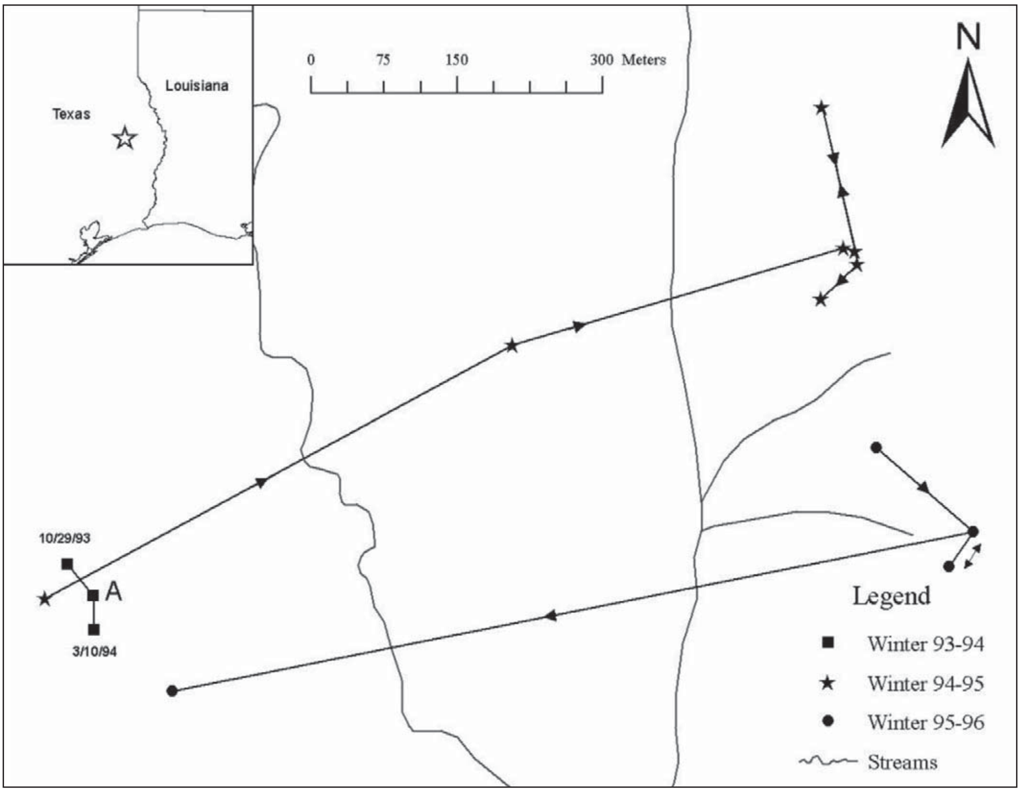

Figure 2. Winter movements of Louisiana Pine Snake Male 1 during 3 successive winters in the Angelina National Forest, TX. Arrows indicate direction of movement.

March–May and September–November, we found movement frequencies to be the highest during April–August. Himes et al. (2006a) found no snakes in the open during the winter months (December–February), while we found snakes were comparatively active (mean = 24%) during that part of the year. Our study includes the same snakes used by Himes et al. (2006a); however differences in the calculation of activity exist between studies. Himes used percentage of observations of snakes located in the open as an indicator of activity. In contrast, we used movement frequency as an indicator of activity, defined as the frequency of geographically different (≥5 m apart) subsequent relocations. The disparity between the winter activity patterns of Louisiana Pine Snakes in these studies is likely a combination of the differences between the definition of activity, and the increased sample size of snakes in our study.

There is a considerable amount of variation in the details of winter dormancy within *Pituophis*. Use of previously occupied sites in successive years by multiple individuals is typically reported in more northern populations (Burger et al. 1988, Kapfer et al. 2008, Parker and Brown 1980, Schroder 1950). These sites are relatively long lasting and allow access to greater depths. More southern populations tend to take refuge individually in more temporary (e.g., downed logs and gopher burrows) and superficial sites (Duran 1998, Franz 2005, Gerald et al. 2006, Gregory 1984, Rudolph et al. 2007). This pattern is presumably a response to winter temperatures, with snakes in colder climates requiring more reliable and deeper hibernation sites, and those in milder climates able to use generally more abundant and superficial sites (Rudolph et al. 2007, Sexton and Hunt 1980).

Rudolph and colleagues (1998) observed the behavior of 3 snakes during the course of 2 prescribed burns in February and March. These snakes simply retreated underground as the fire approached them, and were then insulated from the effects of the passing fire. Six other radio-tagged snakes were known to have survived exposure to the prescribed burns without any apparent damage. They concluded that prescribed fire is not a serious threat to the survival of Louisiana Pine Snakes in fire-dependent climax pine communities.

In contrast, Louisiana Pine Snakes have been found dead on the surface during logging operations during active season months, presumably due to mortality caused by logging machinery (D.C. Rudolph, unpubl. data). Thus, it has been hypothesized that impacts of management practices would be less severe during the winter, when snakes are more often underground. Although snakes move less frequently (and presumably shorter distances) during winter, the impacts of management are still unknown during this time period. While snakes may remain underground more often during winter, impacts from heavy machinery may still be detrimental to snakes occurring only 13–25 cm underground, especially because then they are less capable of moving away from potential threats. Therefore, management practices that involve subsurface soil disturbance in areas known or suspected to support populations of Louisiana Pine Snakes should be carefully evaluated before being undertaken.

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