

Pine Snake (*Pituophis ruthveni* and *Pituophis melanoleucus lodingi*) Hibernacula

D. C. RUDOLPH,^{1,2} R. R. SCHAEFER,¹ S. J. BURGENDORF,^{1,3} M. DURAN,⁴ AND R. N. CONNER¹

¹Wildlife Habitat and Silviculture Laboratory (maintained in cooperation with the College of Forestry, Stephen F. Austin State University), U.S.D.A. Forest Service, Southern Research Station, 506 Hayter St., Nacogdoches, Texas 75965, USA

⁴The Nature Conservancy, 2246 Versailles Drive, Corpus Christi, Texas 78418, USA

ABSTRACT.—Snakes are often highly selective in the choice of sites for hibernation, and suitable sites can potentially be a limiting resource. Hibernating Louisiana Pine Snakes (*Pituophis ruthveni*; $N = 7$) in eastern Texas and Black Pine Snakes (*Pituophis melanoleucus lodingi*; $N = 5$) in Mississippi were excavated to characterize their hibernacula. *Pituophis ruthveni* hibernated exclusively in burrows of Baird's Pocket Gophers (*Geomys breviceps*), whereas *P. m. lodingi* hibernated exclusively in chambers formed by the decay and burning of pine stumps and roots. All snakes hibernated singly at shallow depths (*P. ruthveni* mean = 19 cm, max. = 25 cm; *P. m. lodingi* mean = 25 cm, max. = 35 cm). *Pituophis* taxa at higher latitudes and elevations hibernate communally and at greater depths. In contrast to Northern Pine Snakes (*Pituophis melanoleucus melanoleucus*), none of the pine snakes in our study excavated hibernacula beyond minimal enlargement of the preexisting chambers. These differences are presumably the result of mild winters, an abundance of suitable sites offering sufficient thermal insulation, and reduced predation risk caused by absence of communal hibernation in traditional sites. It is increasingly apparent that, throughout their annual cycle, pine snakes are dependent upon fire-maintained pine ecosystems.

Snakes of the genus *Pituophis* (Colubrinae) are widespread in North America (Sweet and Parker, 1991). Members of the genus prey primarily on small mammals and exhibit morphological and behavioral adaptations for soil excavation (Carpenter, 1982; Knight, 1986; Burger et al., 1988; Burger and Zappalorti, 1991). *Pituophis* taxa of the eastern United States, which we will refer to collectively as pine snakes, exist as isolated populations, are generally uncommon to rare, and their ecology is not well known (Sweet and Parker, 1991; Reichling, 1995). Both the Louisiana Pine Snake (*Pituophis ruthveni*) and the Black Pine Snake (*Pituophis melanoleucus lodingi*) are closely associated with fire-maintained pine communities (Rudolph and Burgdorf, 1997; Duran, 1998; Rudolph et al., 2006). Because of land use changes and alteration of fire regimes, the longleaf pine (*Pinus palustris*) forests and related fire-dependent communities of the southeastern United States are highly endangered (Platt, 1988; Frost, 1993; Conner et al., 2001). As a consequence, *P. ruthveni* and *P. m. lodingi* are of conservation concern.

Across their range, *Pituophis* spp. hibernate in a variety of den types (e.g., rock outcrops

[Schroder, 1950; Woodbury and Hansen, 1950; Parker and Brown, 1973]), wherein the dens are potentially of considerable depth, as well as den sites in soil that are excavated by the snakes themselves (Burger et al., 1988). Hibernacula used by *Pituophis* spp. typically contain multiple individuals and often multiple species (Woodbury, 1951; Burger et al., 1988).

Based on concurrent radiotelemetry studies, we hypothesized that *P. ruthveni* and *P. m. lodingi* hibernated individually at shallow depths. We excavated hibernating *P. ruthveni* and *P. m. lodingi* to characterize the hibernacula used by these snakes and to determine the number of snakes using individual sites.

MATERIALS AND METHODS

Study Areas and Subjects.—Radiotelemetric studies of pine snakes were conducted in the states of Texas (Angelina and Jasper Counties, 31°9'N, 94°22'W; Newton and Sabine Counties, 31°7'N, 93°45'W), Louisiana (Bienville Parish, 32°30'N, 93°1'W; Vernon Parish, 31°8'N, 93°16'W), and Mississippi (Perry County, 31°5'N, 89°16'W). We monitored 18 *P. ruthveni* and 17 *P. m. lodingi* that had been previously captured in drift fence/funnel traps (Rudolph and Burgdorf, 1997; Duran, 1998; Burgdorf et al., 2005), implanted with radio transmitters (Rudolph et al., 1997; Duran, 1998), and released at their point of capture. From the cohort of snakes available during the winters of 1995–1996 and

²Corresponding Author. E-mail: crudolph01@fs.fed.us

³Present address: U.S. Fish and Wildlife Service, 510 Desmond Drive, Suite 102, Lacy, Washington, USA 98503-1263

TABLE 1. Characteristics of hibernation sites of Louisiana Pine Snakes (*Pituophis ruthveni*) and Black Pine Snakes (*Pituophis melanoleucus lodingi*). All measurements in centimeters. Only two dimensions given for root tunnels because total length was unknown.

Species	Date	Burrow type	Depth	Distance from entrance	Chamber dimensions
<i>P. ruthveni</i>	04 Dec 96	<i>Geomys</i>	25	75	loose dirt only
<i>P. ruthveni</i>	13 Dec 95	<i>Geomys</i>	17	18	8 × 6 × 18
<i>P. ruthveni</i>	12 Jan 96	<i>Geomys</i>	24	21	6 × 10 × 16
<i>P. ruthveni</i>	01 Jan 96	<i>Geomys</i>	22	60	14 × 15 × 12
<i>P. ruthveni</i>	01 Feb 96	<i>Geomys</i>	13	15	7 × 10 × 8
<i>P. ruthveni</i>	01 Feb 96	<i>Geomys</i>	13	54	9 × 15 × 18
<i>P. ruthveni</i>	03 Feb 96	<i>Geomys</i>	19	35	7 × 17 × 24
<i>P. m. lodingi</i>	05 Feb 97	root tunnel	25	25	4 × 5
<i>P. m. lodingi</i>	05 Feb 97	root tunnel	35	80	6 × 5
<i>P. m. lodingi</i>	05 Feb 97	beneath stump	27	0	20 × 25 × 10
<i>P. m. lodingi</i>	05 Feb 97	root tunnel	9	73	8 × 6
<i>P. m. lodingi</i>	04 Feb 97	root tunnel	28	135	7 × 6

1996–1997, seven *P. ruthveni* and five *P. m. lodingi* were selected for investigation of their hibernacula. *Pituophis ruthveni* (104–134 cm SVL) were excavated in the Sabine National Forest, Sabine County, Texas ($N = 2$), Angelina National Forest, Jasper County, Texas ($N = 2$), and Bienville Parish, Louisiana ($N = 3$). All five *P. m. lodingi* ($N = 5$, 103–160 cm SVL) were excavated at Camp Shelby, Perry County, Mississippi. All sites were in fire-maintained longleaf pine habitats with a relatively open canopy (60–90% canopy closure) and abundant herbaceous vegetation (for additional habitat descriptions, see Rudolph and Burgdorf, 1997; Duran, 1998; Ealy et al., 2004; Himes et al., 2006a,b). Throughout the text, means appear ± 1 SD.

Field Methods.—We considered a hibernaculum to be any subterranean location occupied during December, January, or February. We dug complete or partial trenches around snake locations (determined by telemetry) at a radius of 1 m and a depth of 0.5 m, thereby isolating the snakes, exposing the tunnels they occupied, and allowing careful excavation of the tunnels leading to the actual snake locations. Telemetry signals were continuously monitored during excavation so that snake movements could be detected.

RESULTS

Eighteen *P. ruthveni* were located in 30 separate hibernacula over the course of the radiotelemetry study. Dates of hibernation were difficult to determine because of minor, and sometimes major, movements in all months. Very generally, *P. ruthveni* ceased most surface activity between mid-October and the end of November and initiated surface activity between mid-February and the end of March. All *P. ruthveni* hibernacula (i.e., sites used between

December and mid-February) were within the individual's home range as determined by radiotelemetry during the preceding active seasons. A total of 17 *P. m. lodingi* were located at 17 separate hibernacula. *Pituophis melanoleucus lodingi* arrived at hibernacula as early as mid-October; however, most were present at hibernacula between early December and late March. We did not observe any pine snakes to use the same hibernacula in successive years.

We never detected more than one pine snake at a given site, although one *P. m. lodingi* was located within 1 m of an adult Eastern Coachwhip (*Masticophis flagellum*). Twelve hibernating *Pituophis*, a subset of the 35 available, were excavated during hibernation. All seven *P. ruthveni* excavated were located in burrows of Baird's Pocket Gophers (*Geomys breviceps*) at a mean depth of 19.0 ± 4.93 cm with a range of 13–25 cm (Table 1). Hibernation sites of additional *P. ruthveni* ($N = 23$), as inferred by radiotelemetry and surface observation, were consistent with use of pocket gopher burrows as hibernation sites. The mean distance to the nearest gopher mound, measured along the path of the gopher burrow, was 39.7 ± 23.5 cm with a range of 15–75 cm. In all cases, evidence of snake excavation was noted at the gopher mound where the snake gained entrance to the burrow system. The entrance tunnels were not open, having been backfilled by the snake or more likely simply collapsed over time. Based on the presence of freshly mounded soil, three of the seven burrow systems that contained pine snake hibernacula were occupied by gophers. In all three of these active burrow systems, the resident gopher had packed in soil to plug the tunnel leading to the snake. The distribution of recent mounds suggested that the portion of each burrow system containing a hibernaculum was not being actively used by the gopher.

Individual *P. ruthveni* occupied short lengths of the pocket gopher burrow that appeared to have been enlarged, presumably by the resident snake. There was no evidence that soil was actually excavated to form the hibernating chamber. Our observations suggested that the snakes compressed the loose soil of the walls to enlarge the chamber volume. These chambers had a mean width of 12.2 ± 4.17 cm, a mean height of 8.5 ± 2.88 cm, and a mean length of 16.0 ± 5.51 cm (Table 1). They tapered gradually in width and height at each end to the dimensions of typical pocket gopher burrows.

All five *P. m. lodingi* hibernacula were excavated in decayed and burned stumps of longleaf pine (Table 1). Hibernation sites of additional *P. m. lodingi* ($N = 12$), based on radiotelemetry and surface observation, were also consistent with use of chambers resulting from decay and burning of pine stumps, although this could not always be determined from surface observation. Of the *P. lodingi* excavated, one was located directly beneath the stump of a pine at a depth of approximately 27 cm, in a 20×25 cm chamber approximately 10 cm in height. The four remaining *P. m. lodingi* were located in sinuous, horizontal cavities created by the decay or combustion of lateral roots. Such channels could extend several meters from the location of the original pine stump. Mean depth of hibernating snakes was 24.8 ± 9.60 cm, with a range of 9–35 cm. The mean distance from the point of entrance to the snake locations, measured along the path of the channel, was 62.6 ± 52.4 cm, with a range of 0–135 cm.

In three instances, decay and fire had consumed the original stump leaving vertical-sided holes with a depth of 25–42 cm and a width of 16–27 cm. The associated root channels opened on the sides of the vertical holes. In the site with the intact stump, vertical openings adjacent to the sides of the stump allowed access to the root channels. These openings appeared to be erosional in origin, rather than excavated by the snakes. The final site was represented on the surface by a vegetated depression approximately 40 cm in depth and 150 cm in width. Remnants of a stump were found below the soil surface in this depression. A burrow, perhaps partially excavated by the snake, allowed access to an intact root channel at the approximate location of the original stump.

At the time of excavation, air temperatures (thermometer measurements) ranged from -1 to 22°C and temperatures at the actual snake locations ranged from 6.5 – 10.5°C . During excavation, one snake (chamber temperature 10.5°C) moved approximately 2.5 m in an apparent attempt to escape. The data were too sparse

and variable to provide any insight into variation in depth of snakes throughout the hibernation period. However, *P. ruthveni* were perhaps constrained by the relatively consistent depth of the gopher feeding tunnels. Pine snakes could only hibernate at greater depths by actively digging, or by entering tunnels that led to nest chambers. Over the course of the radiotelemetry study, we never observed *P. ruthveni* to enter these deeper nest chambers. *Pituophis melanoleucus lodingi* faced similar restrictions because most root channels were essentially horizontal.

DISCUSSION

Pituophis ruthveni and *P. m. lodingi* hibernate as single individuals in preexisting chambers at relatively shallow depths. We found *P. ruthveni* exclusively using the relatively shallow foraging burrows of *G. breviceps* for hibernation, avoiding the deeper burrows associated with the pocket gopher nesting chambers. In addition, snakes were located <1 m from the presumed point of entrance into the burrow system. This placement is similar to the positions occupied by *P. ruthveni* at other seasons when using pocket gopher burrows for foraging and refuge (Rudolph and Burgdorf, 1997; Rudolph et al., 1998, 2002). *Pituophis ruthveni* minimally modified the existing burrows by excavating a short entrance tunnel through a nearby pocket gopher mound and slightly enlarging the existing burrow to form a chamber at the site of hibernation. Franz (2001) has described the excavating behavior of Florida Pine Snakes (*Pituophis melanoleucus mugitus*) allowing entrance into pocket gopher burrows through the mounds. *Pituophis ruthveni* hibernacula were physically isolated from the remainder of the associated burrow systems by the actions of resident gophers; hibernacula were isolated from the surface by tunnel collapse.

Pituophis melanoleucus lodingi, which is not sympatric with *Geomys* spp. (Hall, 1981), were found to hibernate exclusively in chambers formed by decayed or burnt pine stumps and associated roots. Stumps were either present, absent leaving a vertical pit, or absent with little surface indication of their existence resulting from erosional filling of the pit and revegetation of the surface. In four of five hibernacula, snakes were in root channels, and the chamber was <1 m from the entrance. The mean depth of the actual points of hibernation were slightly deeper (25 vs. 19 cm) than those of *P. ruthveni* reflecting the average depths of pine roots compared to pocket gopher foraging tunnels. We found no evidence of any modification of the preexisting chambers associated with

stumps and roots, and the routes of access to the actual site of hibernation remained open to the surface. In addition, similar sites were the most frequent subterranean sites occupied by *P. m. lodingi* during the active season (Duran, 1998).

Mount (1975) and Jordan (1995) assumed that *P. m. lodingi* made extensive use of Gopher Tortoise (*Gopherus polyphemus*) burrows, including for hibernation. Jennings and Fritz (1983) reported observations of *P. m. lodingi* retreating into *G. polyphemus* burrows. Despite a substantial *G. polyphemus* population at our Mississippi study site, we never detected use of *G. polyphemus* burrows for hibernation by *P. m. lodingi*. During the entire period that *P. m. lodingi* were radiotracked, we only observed three instances of snakes entering abandoned *G. polyphemus* burrows (Duran 1998). Neither did we record use of the abundant armadillo (*Dasypus novemcinctus*) burrows as hibernation sites by either species at any of our study sites. Perhaps the large diameters of these burrows allow access to a wide array of potential predators. Tortoise and armadillo burrows may be of greater importance to other *P. m. lodingi* populations where the abundance of pine stumps is limited. Franz (2005) documented substantial use of *G. polyphemus* burrows by *P. m. mugitus* in Florida, including for hibernation and as general subsurface retreats.

A number of factors may account for the differences between the hibernacula of pine snakes and their congeners. In colder climates (higher altitude or latitude), snakes require greater insulation from surface temperatures. This protection is generally achieved by hibernating at greater depths (Sexton and Hunt, 1980; Gregory, 1984). In many geological settings, rock outcrops provide the primary access to safe depths. These sites are often limited, and communal hibernation is common (Gregory, 1984). *Pituophis* in Utah (Parker and Brown, 1973) and Illinois (Schroder, 1950) exhibit this strategy. In the Pine Barrens of New Jersey, a high latitude, Atlantic Coastal Plain habitat lacking rock outcrops, Northern Pine Snakes (*P. m. melanoleucus*), excavate communal hibernacula, often associated with stumps or existing mammal burrows (Burger et al., 1988). The mean depth of 79 cm for *P. m. melanoleucus* hibernacula in New Jersey (40°10'N) is conspicuously greater than the mean depths we recorded for pine snakes in TX/LA/MS (31°5'N to 32°30'N).

Despite the lack of rock outcrops on the Gulf Coastal Plain, the combination of comparatively mild winters and numerous preexisting chambers (*Geomys* burrows and fire-killed pines) has historically meant an abundance of hibernation

sites. This overwintering strategy avoids the energy costs of excavation, as well as the energy costs and predation risks of migration to a traditional hibernaculum whose location can potentially be learned by predators (Burger et al., 1992). Consequently, there is presumably less selection pressure for use of sites that provide more protection (i.e., rock outcrops or greater depths).

The availability of suitable hibernation sites is influenced by forest management. Pocket gophers are dependent on herbaceous vegetation as a food source (Williams and Cameron, 1986). Suppression of fire favors woody encroachment and reduces the food base for gopher populations, thereby potentially affecting snake populations. This change has been associated with declines and extirpations of *P. ruthveni* (Rudolph and Burgdorf, 1997; Rudolph et al., 2006).

Decayed and burned stumps are initiated by tree mortality caused by logging or more natural factors. Intensive site preparation involving the removal of stumps prior to replanting, combined with younger harvest ages of trees, precludes the development of suitable hibernation sites of the type used by *P. m. lodingi*. Alteration of fire regimes, typically resulting in less frequent fires, may also impact the availability of suitable sites associated with stumps and roots. Stumps remaining from the original harvests of longleaf pines in the early 1900s are still suitable for use by amphibians and reptiles (Means, 2005, 2006). Harvest of these residual stumps for naval stores can potentially reduce the availability of hibernation sites (Means, 2006). It is increasingly apparent that, throughout their annual cycle, pine snakes are dependent upon fire-maintained pine ecosystems. Consequently, restoration of a frequent fire regime is the most critical management need required to maintain viable populations of these species.

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