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Journal of Herpetology, Vol. 26, No. 3, pp. 259–263, 1992

Subterranean Predation on Pine Snakes (*Pituophis melanoleucus*)

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ABSTRACT.—**We examined subterranean predation rates in the hibernacula (1986-1991) and nesting burrows (1976-1991) of pine snakes (*Pituophus melanoleucus*) in the New Jersey Pine Barrens. We examined 40 hibernacula with 412 snakes. Snakes were killed by red fox (*Vulpes fulva*, n = 1), striped skunk (*Mephitis mephitis*, n = 2) and short-tailed shrew (*Blarina brevicauda*, n = 5). We examined 201 snake nests: 42 were dug up by foxes, 7 were dug up by skunks, and in one a scarlet snake (*Cemophora coccinea*) was eating an egg. Over three years we found that humans illegally removed the eggs in 23 of 80 pine snake nests.**

Predation on reptiles is generally thought to be an important cause of mortality, particularly for small or young animals, but usually incidents of predation are difficult to observe directly. Observations of predation on snakes are rare, and of subterranean predation almost unknown. Most evidence for subterranean predation comes from circumstantial evidence such as tracks or scats visible on the surface. Predation on nests and eggs, however, is fairly well documented because predators dig up the nests, leaving recognizable signs (Moll and Legler, 1971; Burger, 1977; Dodd, 1988).

Iguana eggs are often chewed by inverte-

brates, millipedes, and ants (Rand and Dugan, 1980), but it is unclear whether this is the cause of, or merely follows, egg mortality. Many species prey on the eggs of turtles, including insects, crustaceans, reptiles, birds, and mammals, including man (Chavez et al., 1967; Moll and Legler, 1971; Burger, 1977; Dodd, 1988). These predators often dig up nests and destroy the whole clutch. Predation on eggs while they are in the nest is usually not reported, and it is difficult to distinguish predation from death followed by scavenging. Partially, this reflects the difficulty of finding reptile nests. Similarly, hibernating reptiles are seldom amenable to a study of predation because few hibernacula have been studied repeatedly (but see Carpenter, 1953; Parker and Brown, 1973), and few incidents of predation in hibernacula have been reported.

In this report we describe subterranean predation on pine snakes (*Pituophis melanoleucus*) in the New Jersey Pine Barrens. We have been examining pine snake nests for 15 years and snake hibernacula for 6 years, and have observed predation on both eggs and snakes. Female pine snakes excavate nests below the ground for their eggs (Burger and Zappalorti, 1986, 1991), and pine snakes excavate their own hibernacula or extend the abandoned burrows of mammals as hibernacula (Burger et al., 1988).

Methods

From 1976 to 1991 we studied the nesting behavior of pine snakes in the New Jersey Pine Barrens (Burger and Zappalorti, 1986, 1988, 1991; Zappalorti et al., 1983; Zappalorti and Burger, 1986). We searched 15–16 known breeding areas (up to 1.5 ha in size) from 15 June–20 July (2–6 times/area) in Burlington and Ocean counties, New Jersey, and excavated nests, replacing the clutches in their nests after examinations (other pine snake clutches not included in this study were removed and incubated in the laboratory). We monitored nests throughout the summer until they were predated or the young hatched. We determined that young emerged from the nest by the presence of shed skins, hatchling trails in soft sand, or depressions where young emerged. Red fox (*Vulpes fulva*) and striped skunk (*Mephitis mephitis*) dug different-sized holes when they were excavating nests. Foxes dug large holes, placed excavated sand in a large dump pile, and often left footprints; skunks also left footprints but made smaller holes, produced more scattered dump piles; both left partially eaten egg shells around.

We also noted when nests were dug up by human poachers. Since humans can follow an underground nest tunnel, their excavations were neat, they left handprints or footprints and no eggshells, and they sometimes covered over the empty nests. It was usually impossible to determine whether a human predator found eggs, a gravid female, or a spent female.

From 1986–1991 we studied 40 hibernacula of pine snakes located in the vicinity of nesting areas (Burger et al., 1988). We dug up the hibernacula by shovels and by hand, noting the location and condition of all snakes (see Burger et al., 1988, for methods). All hibernacula were rebuilt (Frier and Zappalorti, 1983), and pine snakes were returned after marking and measuring.

Results

Predators and Incidence of Natural Predation.—From 1976–1991 we studied 201 pine snake nests that were left undisturbed so that the young could hatch and emerge. During this period we found that 21% were dug up by red foxes, and less than 1% were dug up by striped skunks (Table 1). We only examined human poaching rates from 1988–1990, yet in this period 29% of the nests or nest sites that we found were dug up by people. When we found these disturbed nests there were no eggs, and the humans could have taken either a gravid female that was digging her nest, the clutch, or both.

We also observed an adult male scarlet snake (*Cemophora coccinea* SVL = 28.2 cm) eating a pine snake egg in a nest (Table 1). The scarlet snake's head was partially in one egg, with an empty egg shell attached. The other eggs were intact. Over the years we have observed numerous incidents of nests being dug up by foxes or skunks (Table 1), but the scarlet snake observation is our only known case of subterranean predation on eggs. Foxes and skunks both dig up pine snake nests, leaving a gaping hole, with discarded shells scattered about the surface containing teeth marks on them.

Subterranean Predation in Hibernacula.—During our hibernation study we observed fox predation on one adult pine snake, skunk predation on one adult and one yearling pine snake, and shrew predation on five hatchling pine snakes. Foxes and skunks merely dug down in the burrow and ate the snake, whereas the shrew possibly gained secondary access to the hibernaculum by following the same entrance the snakes used.

In 1986 and 1987 in two different hibernacula we observed dead snakes that were partially eaten in a characteristic manner: A 3-cm section of the snake's body was removed from the center, including the vertebrae. The ventral skin remained intact, however, connecting the two sections of the snake. Although we took detailed notes, we were unable to identify the predator until 1990.

TABLE 1. Subterranean predation on pine snakes (*Pituophis melanoleucus*) while nesting or while hibernating in southern New Jersey. The same hibernacula were dug up each year. Nests were obliterated during the season because the sand fills in the tunnels.

	Hibernacula	Nesting burrows
Years of study	1986–1991	1976–1991
Number of years studied	6	15
Number of hibernacula or nests examined	40	201
Number of snakes located	412	—
Predation on snakes or nests		
Red fox (*Vulpes fulva*)	1	42
Striped skunk (*Mephitis mephitis*)	2	7
Short-tailed shrew (*Blarina brevicauda*)	5	0
Scarlet snake (*Cemophora coccinea*)	0	1
Human poaching		
Number of years studied	6	4
Number of hibernacula or nests examined	40	80
Number poached	0	23

On 9 March 1990 we excavated one hibernaculum which had been excavated for four previous years without incident of predation (Fig. 1). The snake entrance (18 × 12 cm hole) at the surface was in the place it had been in the three previous years, but 60 cm to the side a much larger hole was excavated by a skunk, judging from the odor surrounding the hole. The skunk tunnel led down to a chamber 96 cm below the surface where there was one living 2 yr old pine snake (77 cm SVL) and one hatchling (43 cm SVL) that was almost entirely eaten, except for the skin and skeleton. The snake's remains had several skunk hairs attached. The skunk tunnel led to one side, where it was enlarged from the usual snake tunnel size (about 3 × 3 cm; Burger et al., 1988). Although the hatchling may have been killed and partially eaten by the skunk, it may have also been eaten by a shrew.

The main snake entrance led down into a system of subterranean tunnels. Some tunnels had larger side chambers containing snakes, whereas others had snakes hibernating in the tunnels themselves (Fig. 1). In one of the small side tunnels (111 cm below the surface), we found one bloody, recently-killed hatchling (SVL = 44.5, male) with sections of its skin intact, but with a 3.5 cm long section of the body entirely eaten, leaving only the skin without any skeleton. In a connecting tunnel (120 cm below the surface) we found another hatchling (SVL = 43 cm, female) in the process of being eaten by a short-tailed shrew (*Blarina brevicauda*).

When removed, the hatchling was still alive and moving, even with a 4.5 cm long section removed from its midsection, and the shrew had pieces of snake tissue in its mouth. The appearance of the bites and wounds on the two hatchlings was similar. When dissected, the shrew had snake tissue and bone its stomach. Completing the excavation, the hibernaculum had 19 living pine snakes and one living black racer (*Coluber constricter*) in addition to the three partially-eaten pine snake hatchlings (Fig. 1). Of the 19 live pine snakes, only two other hatchlings were found at a depth of 130 cm. The hatchlings preyed upon by the shrew appeared healthy and were of normal body mass.

In this hibernaculum three of the five hatchlings were killed by predators, whereas none of the larger snakes were preyed upon. Although it may be chance which snakes the shrew encountered, six adults were closest to the surface entrance, yet the shrew killed two hatchlings here. Since both hatchlings and adults were at ambient temperature (about 5–7 C), they were generally immobile and would not offer much resistance to the shrew. Further, the thicker, tougher skin of the adults might protect them.

Other Causes of Overwinter Mortality.—In 1990 one adult female snake seemed to be forced from a hibernaculum by fire. The area burned one to two weeks before we dug up the hibernaculum, and we found the female dead on the surface 2 m from the entrance, severely burned. In the same year at another natural den one adult female and three hatchlings died, apparently from the cold when they failed to go deeper than 0.3 m below the surface in the fall.

DISCUSSION

Pine snakes dig burrows for summer dens, hibernacula, and nest sites. The tunnel system for summer dens and for winter hibernacula extend to 1.5 m below ground, and may involve horizontal tunnels that extend up to 3 m lat-

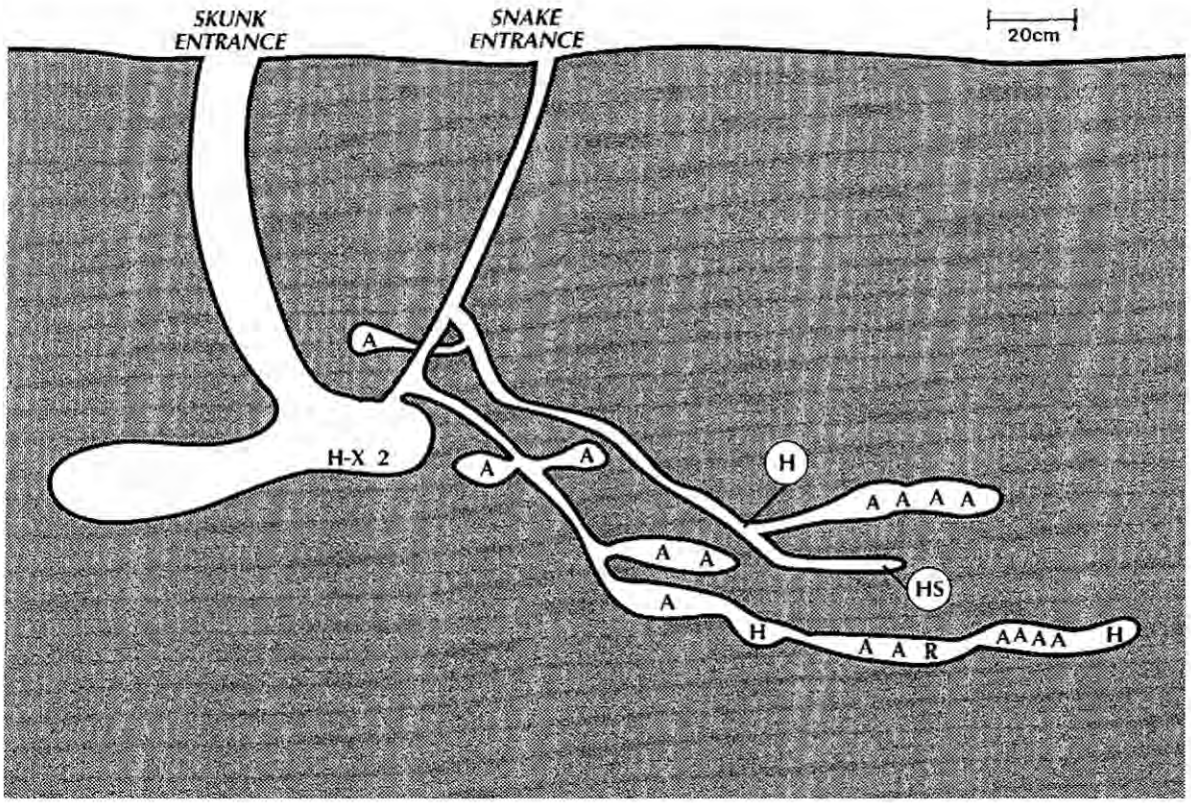

FIG. 1. Diagrammatic sketch of a New Jersey hibernaculum in 1990 showing location of pine snakes (*Pituophis melanoleucus*). Abbreviations are as follows: A = adult pine snake, H = hatchling pine snake, 2 = 2 year old pine snake, R = black racer (*Coluber constrictor*). Abbreviations of observed predation events are: H-X = the location of striped skunk (*Mephitis mephitis*) predation, H (in a circle) = the location of a pine snake hatchling preyed upon by a short-tailed shrew (*Blarina brevicauda*), and HS = the location of the live pine snake hatchling being eaten by a shrew.

erally (Burger et al., 1988). Nest burrows, on the other hand, are considerably shallower, but may also extend up to 3 m long (Burger and Zappalorti, 1986). All of these burrow systems and tunnels are potentially accessible to predators because the surface entrance is open. Summer dens and hibernacula may have one to three openings, and these remain open throughout the year unless they become clogged by blowing leaves or debris. When female pine snakes excavate a nest burrow they do not fill the tunnel, nor do they obscure the opening. They simply leave, and a large dump pile of lighter sand remains as a marker for natural predators or human poachers. With pelting rains the nest tunnels eventually fill in, but the dump pile may be obvious for weeks.

Other reptiles that dig nests usually cover the nest opening and obliterate their nesting sites. Nesting iguana (*Iguana iguana*) push an earthen plug down the burrow, and continue to scratch the earth for several meters around the nest, making the exact nest site difficult to locate (Rand, 1968), as do other lizards (Van Devender and Howard, 1973). Turtles such as the diamondback terrapin (*Malaclemys terrapin*) and sea turtles (*Chelonia; Caretta*) also cover their nests, and spend time moving the sand over the nest site to obscure its location (Burger and Montevecchi, 1975; Burger, 1977).

Pine snakes, on the contrary, make no effort to hide their nests, or even fill the entrance. Given the difficulty of digging, and their lack of limbs, this is perhaps not surprising. Females could, however, move sand back over the nest entrance with their heads or bodies. Iguanas plug their nests by using their snouts (Rand, 1968). Turtles use their hind legs to cover their nests (Burger and Montevecchi, 1975). Nonetheless, compared to predation rates in turtle nests (60–85%; Burger, 1977), pine snake nests suffer lower predation rates (36%).

The vulnerability of pine snakes to predators during the winter is increased by their inactivity and aggregation. A shrew, skunk, or fox that locates a hibernaculum may have up to 31 snakes to eat (Burger et al., 1988; Burger and Zappalorti, unpubl. data). For large predators such as a red fox or striped skunk it may not be worth the energy costs to excavate such long tunnels to find the snakes, and this may account for our relatively low rate of predation at hibernacula.

Short-tailed shrews, however, are not required to excavate to reach their prey as they can move easily within the burrow system of the snakes. During the winter, the snakes are inactive, and vulnerable, and the hatchling we observed being eaten was making no attempt to escape.

Shrews are active all year, using the burrows of other insectivores and rodents (Nowak and Paradiso, 1983). Their normal diet is invertebrates, mice, small vertebrates, and plant material (Nowak and Paradiso, 1983), but we can find no mention of snakes. Most snake nests are difficult to locate, as are hibernacula, making it unlikely for naturalists to observe shrew predation on snakes. During the non-wintering period pine snakes would normally be immune to shrews because they could escape, or even eat them.

Acknowledgments.—Over the years a number of people have helped us locate pine snake nests or excavate burrows, and we thank them now: Dale Bertrand, Bill Boarman, Bill Callaghan, Susan Elgin, Ronald Ford, Steve Garber, Mark Laska, Peter Mooney, Gianluca Rocco, Jorge Saliva, Kevin Staine, Samuel Sweet, Clay Sutton, and Peggy Vargas-Zappalorti.

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Accepted: 27 March 1992.