breeding season, males searched for mates while on migration routes to the stream (Tsuji and Kawamichi 1996a), and they also occasionally waited for females on shore around the pool at night. Such males may be able to intercept newly arriving females to the pool. In general, the males of explosive breeders occur widely around the edges of ponds until spawning commences, whereupon they concentrate around oviposition sites (e.g., *Bufo bufo*, Davies and Halliday 1979; *Rana sylvatica*, Howard 1980). Although this was seen occasionally in *B. torrenticola*, males more often searched and struggled for mates in the deeper parts of the breeding pool. However, lone females commonly were found in shallow water near shore, and paired females were most often found at the communal oviposition site.

Breeding adult *B. torrenticola* showed predominantly nocturnal activity; both sexes were more abundant (Tsuji and Kawamichi 1996a) and more widely distributed in the pool at night than during the day, and almost all toads at the surface or on land were found at night. During the day, however, many toads were found in the relatively deeper parts of the pool. The diurnal breeding activity of *B. torrenticola* may be associated with the early breeding in spring, color dimorphism in visual mate recognition (see discussion in Tsuji and Kawamichi 1996a), and/or underwater breeding.

Besides *B. torrenticola* and members of Pipidae living in the water, underwater breeders are known for the tailed frog, *Ascaphus truei* (Jameson 1955), and the Japanese steam-breeding frog, *Rana sakuraii* (Kusano and Fukuyama 1989), both breeding in fast-flowing streams. Thus, underwater breeding behavior is considered to have evolved independently among anuran groups. The possible benefits of breeding on the bottom of fast-flowing streams include: 1) richly oxygenated waters; 2) low metabolic demands in relatively cold water; 3) relatively stable water temperature; 4) no danger of drying; and 5) predator avoidance (see Olson 1989). On the other hand, possible costs are restricted activity in the water and risk of the eggs being washed away. For two Japanese underwater breeders, *B. torrenticola* and *R. sakuraii*, the most striking adaptation to underwater breeding is enlarged dorsal skin of males (Maeda and Matsui 1989; pers. observ.) that might assist cutaneous respiration in the water and allow them to be vigorously active there.

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PINE

Avoidance of Fire by Louisiana Pine Snakes, *Pituophis melanoleucus ruthveni*

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Wildfire and prescribed fire are important influences on pine ecosystems in the southeastern United States (Komarek 1968, 1974; Platt et al. 1988). Although considerable research on the impact of fire on vertebrates due to changes in vegetation structure has been reported, the direct impact of fire on vertebrates is not well known (Means and Campbell 1981). The Louisiana pine snake (*Pituophis melanoleucus ruthveni*) occupies a limited range in eastern Texas and western Louisiana (Conant 1956; Reichling 1995). Within this range it is generally found on sandy soils in longleaf pine (*Pinus palustris*) savannas (Young and Vandeventer 1988). Historically these longleaf pine savannas were maintained by frequent, low intensity ground fires (Komarek 1968; Platt et al. 1988, 1989). In recent decades wildfire frequencies have declined severely due to suppression efforts, and maintenance of these fire climax communities is currently dependent on prescribed fire (Conner and Rudolph 1989; Landers 1987; Platt et al. 1988; Van Lear 1985).

The association of Louisiana pine snakes with longleaf pine savannas and the dependence of these savannas on frequent fire suggests that Louisiana pine snakes have adapted to frequent fire. The influence of wildfires has declined precipitously in recent decades and prescribed fires have only maintained a substantial ecosystem role in limited situations. We have previously hypothesized that these alterations in the fire regime have resulted in apparent declines and local extirpations of Louisiana pine snakes (Rudolph and Burgdorf 1997). The massive increase in woody midstory vegetation and consequent decline of herbaceous vegetation are hypothesized to have had a detrimental impact on pocket gopher populations (*Geomys breviceps*) and ultimately on Louisiana pine snakes.

Since 1993, radio-transmitters (Holohil Systems Ltd., SI-2T transmitters) have been implanted in Louisiana pine snakes at a variety of sites in Texas and Louisiana using the protocol of Weatherhead and Anderka (1984). These transmitters provide a location signal that varies with temperature, providing an estimate of snake body temperature. Preliminary results of ongoing studies demonstrate that Louisiana pine snakes are associated with sandy soils, savanna habitats with abundant herbaceous vegetation, and presence of Baird's pocket gophers (*G. breviceps*). Louisiana pine snakes spend substantial amounts of time underground, primarily in pocket gopher burrow systems, or coiled on the surface adjacent to entrances to pocket gopher burrow systems (Rudolph et al., unpubl.).

Sites where instrumented snakes were located were periodically prescribe-burned by land managers, providing an opportunity to observe snake behavior during exposure to fire. Habitat at all sites consisted of a longleaf pine overstory with a well developed herbaceous understory dominated by bluestem (*Schizachyrium* spp.) and other grasses. Nine snakes were located in burn areas during 1994–97. All nine snakes survived exposure to the prescribed fires with no apparent damage. Six of the snakes were known to be in the burned areas, but were not under observation during the course of the prescribed burns, and it is not known if they were above or below ground at the time of the fires. Three snakes were under observation during the course of the prescribed fires and observations are detailed below.

A prescribed fire on 25 Februrary 1994 burned the area where an adult female Louisiana pine snake was located. At 1155 h the snake was coiled on the surface 1 m downslope from the burrow it used to access a pocket gopher burrow system where it had hibernated. It remained in this position until the approach of the fire at 1438 h. Immediately prior to the passage of the fire the air temperature was 25°C and the transmitter temperature was 27.5°C. The approaching fire was backing downslope at approximately 5 m per min. with flame heights of 0.5–0.8 m. When the fire front was approximately 15 m from the snake, it began moving downslope away from the fire and the burrow entrance. After progressing approximately 2 m the snake reversed direction and moved toward the approaching fire and into the burrow. The fire was 10 m distant as the snake moved underground. The transmitter temperature immediately began to drop from 27.5°C toward the burrow temperature of approximately 11–14°C. Burrow temperatures for this and other observations were estimated from transmitter temperatures of instrumented snakes located in pocket gopher burrows during the general period of the prescribed fire in question.

A prescribed fire on 10 March 1997 burned the area where two Louisiana pine snakes were located. One snake, an adult female, was coiled on the surface at 1145 h. Numerous pocket gopher mounds were evident but, to avoid disturbing the snake, they were not investigated in detail. The snake was in the same position at 1300 h. as the fire approached. Air temperature was 24°C and transmitter temperature was 27.5°C as the backfire with 0.3–0.6 m flame heights moved downslope at approximately 1 m per min. The snake began moving when the fire was 2 m distant and entered a burrow approximately 5 m distant. The burrow presumably allowed access to the pocket gopher burrow system. The fire passed over the snake's burrow entrance at 1352 h. Transmitter temperature at 1400 h was 22°C and dropping toward the burrow temperature of approximately 12–16°C.

The second snake observed on 10 March 1997, an adult male, was located at 1150 h. moving out of a debris pile. It was inadvertently disturbed in the process of being located and rapidly moved approximately 30 m and sought shelter under grass cover. It was still in this location at 1504 h. as the fire approached. The snake was not visible and was not approached closely because of the risk of disturbing it again. As the fire approached the snake, air temperature was 24°C and the transmitter temperature was 23.5°C. The fire was a backfire moving downslope at approximately 2 m per min with 0.4–0.8 m flame heights. The snake maintained its position under grass cover until the flames were within 20 cm at 1516 h. The snake then emerged from beneath the grass cover and moved rapidly across the slope, parallel to and approximately 1.5 m in front of the fire. After moving 15 m the snake reversed direction and moved 95 m in the opposite direction still paralleling the fire front. When relocated at 1524 h. the snake was underground approximately 2 m in front of the advancing fire. The fire passed over the snake's position at 1533 h. The transmitter temperature was unchanged at this time, but began dropping immediately and had reached 18.5°C by 1715 h. After the passage of the fire, no evidence of an entrance to a burrow was located, although numerous pocket gopher mounds were in the immediate vicinity.

These observations suggest that Louisiana pine snakes are not at excessive risk of death or injury because of frequent fire in fire climax pine communities. Snakes located on the surface near known burrow systems simply retreat underground, even if this requires moving toward the advancing fire. Once underground, presumably at the 10–20 cm depth typical of pocket gopher burrows, they are insulated from the effects of the passing fire. Results of our telemetry studies (Rudolph et al., unpubl.) demonstrate that Louisiana pine snakes are underground, or on the surface within a few meters of known burrows, a large majority of the time. Given the large differences at which the snakes apparently detected the advancing fires, it is impossible to reasonably speculate on the possible cues that they might be using to detect fires. It is very possible that different cues are used in different situations.

Snakes on the surface and not near known burrows may be at greater risk. This would occur primarily when snakes were moving substantial distances; ie. between pocket gopher burrow systems, or had sought temporary surface shelter during moves. The third snake discussed above fits this scenario. Even in this situation, behavior of the pine snake served to minimize risk. The snake's immediate behavior was to move a safe distance away from the fire and then initiate what appeared to be rapid searching for a subterranean retreat. This behavior did not cease until the snake gained an underground retreat, even though movement of just a few meters directly away from the advancing fire would have temporarily removed the risk.

The prescribed fires that have largely replaced wildfires in Louisiana pine snake habitat differ substantially from historical fires (Frost 1993; Komarek 1968). Prescribed fires are typically conducted in late winter-early spring whereas wildfires are/were more frequent later in the growing season. In addition, due to a number of concerns, prescribed fires seldom achieve the intensity of many wildfires. These differences presumably influence the interaction of Louisiana pine snakes and fires, however, comparative data are lacking.

The observed behaviors of these Louisiana pine snakes are sufficient to reduce the risk of mortality or injury to a low level from all but the most rapidly advancing fires that occur in the longleaf pine ecosystem. In all of the observed instances the fires were relatively slowly advancing backfires. The potential for mortality or injury to snakes due to rapidly advancing headfires is presumably greater, especially for snakes without immediate access to a burrow. Wildfires, due to their greater intensity, may pose more of a risk than prescribed fires.

Erwin and Stasiak (1979) and Seigel (1986) reported mortality and injury to several snakes, including *P. melanoleucus*, as a result of prescribed fires conducted in prairie habitats in Nebraska and Missouri. These observations demonstrate that snakes are susceptible to death or injury during fires. The authors of both studies suggested that the timing of fires probably influenced their impact on snakes. Means and Campbell (1981) reported significant mortality of eastern diamondback rattlesnakes (*Crotalus adamanteus*) due to prescribed fires in a longleaf pine ecosystem. All reported instances were of snakes in ecdysis and it was hypothesized that reduced mobility and sensory abilities were associated with the mortality. Similar effects are possible with Louisiana pine snakes, but relevant observations are not available.

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Diel and Monthly Variations in Capture Success of *Phrynosoma cornutum* via Road Cruising in Southern Texas

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Road cruising may be a time-efficient capture method for Texas horned lizards (*Phrynosoma cornutum*) and may yield better capture success per unit effort than systematic searches and funnel and pitfall trapping (Fair and Henke 1997). However, it is unknown if road cruising can be used to assess activity patterns of *P. cornutum*. *Phrynosoma* may show changes in their activity patterns due to season (Fair 1995; Potter and Glass 1931) and ambient temperature (Prieto and Whitford 1971). We hypothesized that *P. cornutum* would be most active and, therefore most vulnerable to collection, during the warmest months, and that *P. cornutum* in southern Texas would exhibit one daily peak in activity during spring and autumn and two daily peaks in activity during summer as suggested by Potter and Glass (1931). We sought to test this hypothesis by collecting information on the success of sighting and capturing *P. cornutum* during road cruising searches throughout a four year period.

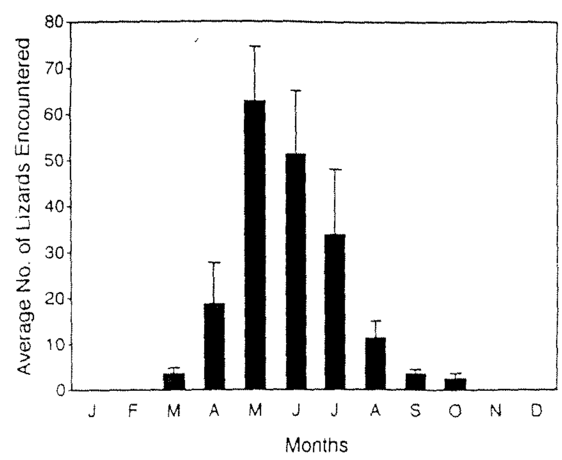

FIG. 1. Average number of *P. cornutum* collected monthly via road cruising during March 1991 to October 1994 in southern Texas. Bars extending above the means are the standard errors of the means. Average number of *P. cornutum* for January, February, November, and December was calculated using three years of data; the average number of *P. cornutum* for the remainder of the months was calculated using four years of data.