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Abstract - We present information on the use of trees by *Elaphe obsoleta* (Texas Ratsnake) in a mesic pine-hardwood forest in eastern Texas. Using radiotelemetry, seven snakes (3 females, 4 males) were relocated a total of 363 times from April 2004 to May 2005, resulting in 201 unique locations. Snakes selected trees containing cavities and used hardwoods and snags for a combined 95% of arboreal locations. Texas Ratsnake arboreal activity peaked during July and August, well after the peak of avian breeding activity, suggesting arboreal activity involves factors other than avian predation.

Introduction

Snakes within the eastern ratsnake complex (*Elaphe obsoleta* Say [Texas Ratsnake], *E. alleghaniensis* Holbrook [Eastern Ratsnake], and *E. spiloides* Duméril, Bibron & Duméril [Gray Ratsnake; following the taxonomy of Burbrink 2001) are well known for their climbing abilities (Durner and Gates 1993, Jackson 1976, Mullin et al. 2000, Stickel et al. 1980); however, time spent in trees varies temporally and/or geographically (Blouin-Demers and Weatherhead 2001, Durner and Gates 1993, Fitch and Shirer 1971, Mullin et al. 2000). Possible explanations for arboreal behavior in snakes include foraging (Beaupre and Roberts 2001), ecdysis (Stickel et al. 1980), escape from predators (Rudolph et al. 2004), oviposition (Brothers 1994, Clark and Pendleton 1995), thermoregulation (Shine et al. 2005), mating (Bullock 1981), and winter dormancy (Stickel et al. 1980). However, the most frequently documented behavior associated with tree use within North American ratsnakes is predation on nesting birds (Aldrich and Endicott 1984; Blem 1979; Fendley 1980; Fitch 1963; Gress and Weins 1983; Hensley and Smith 1986; Jackson 1970, 1978; Mullin and Cooper 2002; Mullin et al. 2000; Neal et al. 1993; Stickel et al. 1980; Withgott and Amlaner 1996). The peak of avian nesting has been shown to overlap with the exploitation of arboreal prey in Texas Ratsnakes in Kansas (Fitch 1963) and Gray Ratsnakes in Ontario (Weatherhead et al. 2003). During avian

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nesting, eggs and juvenile birds are especially vulnerable to consumption by snakes. Therefore, ratsnakes might benefit energetically if arboreal activity coincided with avian nesting. Neal et al. (1993) demonstrated that ratsnakes were more active on *Picoides borealis* Vieillot (Red-cockaded Woodpecker) nest trees during the nesting season. However, other factors such as ecdysis, escape from predators, thermoregulation, mating, and winter dormancy may also play important roles in ratsnake climbing, causing climbing behavior to be the same throughout the active season. Thus, the objective of our study was to describe the arboreal microhabitat use of Texas Ratsnakes in eastern Texas, paying particular attention to their arboreal activity during avian nesting.

Study Area

Our study was conducted on the Stephen F. Austin Experimental Forest (SFAEF) and adjacent private property located approximately 13 km southwest of Nacogdoches, TX. The SFAEF is part of the Angelina-Sabine National Forest and is administered by the USDA Forest Service's Southern Research Station (Wildlife Habitat and Silviculture Laboratory, Nacogdoches, TX). The SFAEF consists of 1036 ha of forest, with bottomland hardwood forest comprising approximately two thirds and upland pine and mesic forests making up the remainder.

The dominant overstory species of the bottomland hardwood forest on the SFAEF are *Quercus lyrata* Walt. (overcup oak), *Fraxinus pennsylvanica* Marsh. (green ash), *Q. phellos* Linnaeus (willow oak), and *Liquidambar styraciflua* Linnaeus (sweetgum). Mesic sites are characterized by overstory trees consisting of *Pinus taeda* Linnaeus (loblolly pine) and *Q. falcata* Michx. (southern red oak), with *Q. stellata* Wangenh. (post oak), *Cornus* sp. (dogwood), *Q. marilandica* Muenchh. (blackjack oak), *Carya* sp. (hickory), *Sassafras albidum* (Nutt.) (Sassafras) Nees, and sweetgum generally composing the midstory (Johnson 1971). The upland pine forest consists mostly of *P. echinata* P. Mill. (shortleaf pine) and loblolly pine, with oak, hickory, and sweetgum being common (Chambless 1971). The SFAEF has been subjected to limited timber harvesting in recent decades, and canopy trees of most forest habitat types are 70+ years old (Conner et al. 2003).

Methods

Radiotelemetry

Snakes were captured with drift fence and funnel-trap arrays (Burgdorf et al. 2005, Fitch 1951) from 29 March to 20 June 2004. Eleven Texas Ratsnakes were equipped with radiotransmitters, but two of the snakes' transmitters were found unattached to the snakes 4 and 6 weeks after release, therefore too few data were obtained for any analyses. Of the remaining nine snakes, seven were used in all data analyses, and two were used in only the arboreal habitat characterization due to their deaths from unknown causes.

Captured individuals were returned to the laboratory where they were weighed to the nearest gram and measured (total length and snout–vent length [SVL]); sex was determined by probing for hemipenes (Schaefer 1934). Each snake was marked by subcutaneous injection of a passive integrated transponder (PIT tag). Transmitters (60 x 11 x 5 mm; ≈6.7 g) were implanted subcutaneously following the techniques of Weatherhead and Anderka (1984). Transmitters weighed <2% of snake body masses. After surgery, snakes were kept in the laboratory and monitored for at least five days, then were released at the point of capture.

Snakes were tracked at various times throughout the day and were relocated at intervals of 2 to 7 days. Relocations were made from 16 April 2004 to 5 May 2005. Relocation site coordinates were obtained using a global positioning system (GPS; Garmin™ eTrex) unit. At each snake location, we recorded air temperature (using a mercury thermometer 1.5 m above ground in a shaded location near the snake), macrohabitat type (upland pine, mesic forest, bottomland hardwood), stand basal area (using a one-factor metric prism), percent canopy closure (using an ocular tube 11.5 cm long by 5.0 cm in diameter), and snake activity (i.e., motionless, basking, traveling). Snakes were considered arboreal when found ≥2 m above the ground in a tree ≥3 cm diameter at breast height (dbh) (Dueser and Shugart 1978). When snakes were found in trees, the height of the snake, tree species, dbh, vine presence, and cavity presence were recorded.

Data analyses

To assess potential influence of arboreal nesting birds on snake microhabitat use, seasons were divided into the general avian nesting season and the peak of avian nesting. The typical nesting season for arboreal nesting birds inhabiting eastern Texas is from March to July, with April and May having the greatest temporal concentration of nesting activities (Hamel 1992). Although colder temperatures did not prevent or eliminate snake movement, climbing activity was reduced. Since we wanted to determine when the snakes use trees most often during the months that are warm enough for them to climb, November, December, January, and February were excluded from monthly arboreal analysis.

To determine whether arboreal locations used by snakes were different than what was available, habitat characteristics of trees used by snakes and randomly selected trees were compared. One random tree was chosen for each arboreal snake relocation by walking 10 to 200 paces (determined by a random number generator) in a randomly chosen direction from each snake relocation site (Blouin-Demers and Weatherhead 2001). The tree nearest to each random location was selected and tree species, dbh, stand basal area, and presence of cavities and vines were recorded and compared to these same characteristics of trees used by snakes. Stand basal area and dbh were compared across used and random locations using paired t-tests. Chi square tests were used to test if snakes occupied trees containing vines and cavities more than expected, and to determine if snakes chose certain tree types (hardwoods, pines, or snags [any dead tree which was either hollow or contained a cavity]) over available tree types. Relocations in trees where snakes were observed more than once were only included once in the analysis of arboreal microhabitat use (Blouin-Demers and Weatherhead 2001). Thus, only the characteristics of unique arboreal microhabitats were compared to characteristics of random trees. All statistical analyses were performed at an alpha level of 0.05 using SAS® software, Version 9 (SAS Institute 2003). Proportional data were arcsine–transformed to achieve normality.

Results

Use of trees

Snake locations were difficult to determine precisely when snakes were positioned high in trees. However, the specific tree could often be determined with a specific cavity or branch identified as the snake location. Snakes (n = 7; 4 males and 3 females) were found in trees (≥2.0 m above ground) during 96 of 363 (26.5%) observations. All three females used trees more often than any male; however, a low sample size precluded statistical comparisons. Male (18 of 38 relocations; 47.4%) and female (15 of 19 relocations; 78.9%) snakes climbed most frequently during July (Fig. 1). Four of seven individuals climbed most frequently during July; only one snake was found in a tree <60% of relocations during July (28.6%).

During the avian nesting season (March–July), snakes used trees proportional to other active months (August–October; $\chi^2 = 0.322$, df = 1, $P = 0.571$). Similarly, tree use did not differ between the peak of avian nesting (April–May) and non-peak (June–October, March) months ($\chi^2 = 2.700$, df = 1, $P = 0.100$).

Arboreal habitat characterization

Only 40 of the 105 (n = 9 snakes) arboreal relocations were unique. The dbh of trees used by snakes (mean = 18.5 cm) was significantly larger than

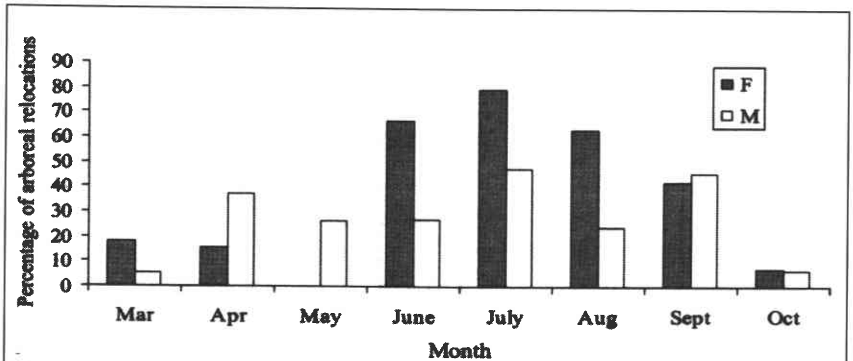

Figure 1. Percentage of relocations in trees by month for *Elaphe obsoleta* (Texas Ratsnakes) from April 2004 to May 2005 in eastern Texas. The avian nesting season is from March to July, with a peak in nesting during April and May.

that of random trees (mean = 11.4 cm; t = -4.39, df = 39, $P < 0.001$). However, stand basal area did not differ between used (mean = 25.5m^2/ha) and random (mean = 27.4m^2/ha) locations (t = -1.46, df = 39, $P = 0.154$). The presence of vines did not differ between used (27.5%) and random (35%) trees ($\chi^2 = 0.524$, df= 1, $P = 0.469$). Cavities, however, were found in 77.5% of the 40 used trees, but in none of the random trees. Snakes used tree types significantly different than those available ($\chi^2 = 13.867$, df = 2, $P = 0.001$). Hardwoods (30 of 40 unique arboreal locations) and snags (6 of 40 unique arboreal locations) were used more often than expected, whereas pines were used less often than expected (4 of 40 unique arboreal locations).

Discussion

Ratsnakes are known to prey on birds (Aldrich and Endicott 1984; Blem 1979: Fendley 1980; Fitch 1963; Gress and Weins 1983: Hensley and Smith 1986; Jackson 1970, 1978; Mullin and Cooper 2002; Mullin et al. 2000; Stickel et al. 1980; Withgott and Amlaner 1996) and small mammals (Fitch 1963, Stickel et al. 1980). Although prey items were not recorded for our population, our snakes did not climb trees most often during the peak of avian nesting, which seems to support the idea that ratsnake climbing behavior is not associated, at least exclusively, with predation on birds (Weatherhead et al. 2003).

At the SFAEF in eastern Texas, arboreally nesting, roosting, or foraging mammalian prey of suitable size for the Texas Ratsnake include *Glaucomys volans* Linnaeus (southern flying squirrel), *Sciurus niger* Linnaeus (eastern fox squirrel), *Sciurus carolinensis* Gmelin (eastern gray squirrel), *Peromyscus gossypinus* LeConte (cotton mouse), *Ochrotomys nuttalli* Harlan (golden mouse), *Neotoma floridana* Ord (eastern woodrat) and microchiropterans (Schmidly 2004). Texas Ratsnakes are known to prey on flying squirrels (Dennis 1971; D.C. Rudolph, US Forest Service, Nacogdoches, TX, pers. comm.), and flying squirrels are abundant in the SFAEF (Conner et al. 1995). Flying squirrels have two nesting seasons, one from March to April, and a second during August (Schmidly 2004), giving ratsnakes potential arboreal prey throughout their activity season.

On 92 of 105 arboreal relocations (87.6%), snakes were located in trees containing cavities. On three occasions, shed skins were observed in tree branches below sites where snakes were previously located. Snakes may have been using trees as pre-molt basking locations, as has been documented for Eastern Ratsnakes (Stickel et al. 1980). In eastern Texas, snakes preferentially climbed trees containing cavities. Cavities within trees may provide snakes a refuge from predators and the elements, and/or access to mammalian prey. In addition to their strong vomeronasal sense (Halpern 1992), snakes use visual cues to locate potential arboreal prey (Eichholz and Koenig 1992, Mullin and Cooper 2002). The presence of a cavity may be a cue used by snakes to climb trees for further investigation (Neal et al. 1993). Thirty-one of 40 unique arboreal locations at the SFAEF were associated with trees that contained cavities, while the remaining 9 trees appeared to be without cavities. Hardwoods were used more often than expected, while pines were used significantly less than expected. The use of hardwood trees in excess of their availability may be linked to the use of cavities. In the southeastern US, in the absence of Red-cockaded Woodpeckers, living pines do not typically contain cavities (Conner et al. 2004), while mature hardwoods often have cavities (Holloway et al. 2007). Snakes used trees that were larger than those chosen at random, perhaps indicating that trees containing cavities are usually mature trees.

In conclusion, Texas Ratsnakes in the SFAEF preferentially climbed large hardwoods containing cavities. Texas Ratsnakes may use trees for access to prey, for basking sites, and/or as predator avoidance sites (Werler and Dixon 2000). The peak of snake arboreal activity did not coincide with the peak of avian nesting, suggesting that avian prey availability is not the primary purpose for climbing.

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