MOVEMENTS OF THE TIMBER RATTLESNAKE (*CROTALUS HORRIDUS*) IN THE SOUTH CAROLINA MOUNTAINS

Jeffrey R. Mohr[1]

ABSTRACT

Although the timber rattlesnake (*Crotalus horridus*) is the most common rattlesnake in the eastern United States, populations have declined and only scattered metapopulations remain in what was once a large and extensive North American range. Whereas some *C. horridus* populations in forest communities of the northeastern and western US have been studied, information on those occurring along the southern part of its range is virtually non-existent. In South Carolina there has been relatively little research done on this species and there has been no formal study on *C. horridus* in the mountainous regions of the state. From 2006 to 2009, I radio-tracked several *C. horridus* in Table Rock State Park, South Carolina and documented their movement patterns. For the duration of the study, males moved a mean annual distance (± SE) of 3,047 ± 488 m, non-gravid females moved a mean (± SE) of 1,688 ± 517 m, and gravid females moved a mean (± SE) of 2,248 ± 597 m. Although mean distances moved were not statistically significant among groups in this study, mean distances travelled for all sexes were much shorter than observed in other populations. I hypothesize that forest management involving natural regeneration and fire suppression, and prey availability may influence *C. horridus* movements in Table Rock State Park.

Key Words: *Crotalus horridus*, timber rattlesnake, movement, fire suppression, forest management.

INTRODUCTION

The timber rattlesnake (*Crotalus horridus*) is a large, heavy-bodied pit viper found in the eastern half of the United States (Fig. 1). Throughout what was once a large and extensive North American range, *C. horridus* populations have severely declined due to purposeful eradication (Klauber 1972; Dodd 1987; Fritsch 1992), hunting, collecting (Galligan & Dunson 1979; Dodd 1987; Reinert 1990; Keyler & Oldfield 1992), and habitat destruction and fragmentation (Martin 1982; Brown 1993; Martin et al. 2008), and only a few scattered metapopulations remain (Martin 1992a). *Crotalus horridus* has been extirpated from Canada, Maine, and Rhode Island (Breisch 1992; Brown 1993), and experts consider it to be vulnerable, imperiled, or critically imperiled in 20 of the 30 states in which it still occurs (Brown 1993; Ernst & Ernst 2003). A proposal submitted to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) by the U.S. Fish and Wildlife Service (2000) indicated *C. horridus* was state-listed as threatened in 4 states (Illinois, New York, Minnesota, and Texas) and endangered in 7 states (Connecticut, Indiana, Massachusetts, New Hampshire, New Jersey, Ohio, and Vermont).

Although *Crotalus horridus* has been relatively well studied in the northern part of its range (Brown 1982, 1991, 1995; Brown et al. 1982; Reinert 1984a, 1984b; Reinert & Zappalorti

[1]Clemson University, Department of Forestry and Natural Resources, Clemson, South Carolina 29634-0317 USA
Current Address: Macon State College, Department of Natural Sciences & Engineering, Macon, Georgia 31206-5145 USA <jeffrey.mohr@maconstate.edu>

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1988; Reinert & Rupert 1999; Aldridge & Brown 1995; Bushar et al. 1998) few studies have focused on populations in the southern part of its range (Gibbons 1972; Sealy 1997; Waldron et al. 2006a, 2006b), despite being listed as a species of concern in some southern states (e.g., South Carolina; SCDNR 2005). Furthermore, with the exception of a study by Sealy (1997), investigations of southeastern populations of *C. horridus* have been limited to those inhabiting the coastal plain ecoregion and very little is known about populations located in the mountains. Although historical records indicate *C. horridus* was common throughout South Carolina (Logan 1859), recent accounts indicate that *C. horridus* is most common in the mountains (located in the northwestern portion of the state) and coastal plain (located along the eastern portion of the state) and tend to be uncommon or absent in much of the intervening landscape (SCDNR 2005; Fig. 2).

Table Rock State Park, located at the edge of the mountainous Blue Ridge ecoregion in Pickens County, South Carolina (Fig. 2), has characteristic upland habitat typical of that used by *Crotalus horridus* (Brown 1993), and sightings of this species on park property have been well documented (S. Stegenga, pers. comm.). At the time of the study, the property consisted of approximately 1,247 ha of upland deciduous forest and had more than 20 km of managed trails (South Carolina Department of Parks, Recreation & Tourism 2010). With the creation of the park in the 1930's, logging and other uses of the land that were previously extensive throughout this locale were curtailed (S. Stegenga, pers. comm.). With the exception of the construction and maintenance of trails, roads, and campground/public use areas, the area that encompasses the park remained in a state of deciduous forest regeneration with suppression of all fires (S. Stegenga, pers. comm.).

In an effort to build a better species portfolio for *Crotalus horridus* in the southern mountainous region of its range, I employed a radio telemetry study of *C. horridus* in the foothills of South Carolina. Specifically, I examined movement patterns of *C. horridus* as these patterns can elicit a multitude of information including habitat association (Brown 1982), foraging areas (Reinert et al. 2011), and egress/ingress routes (Brown et al. 1982).

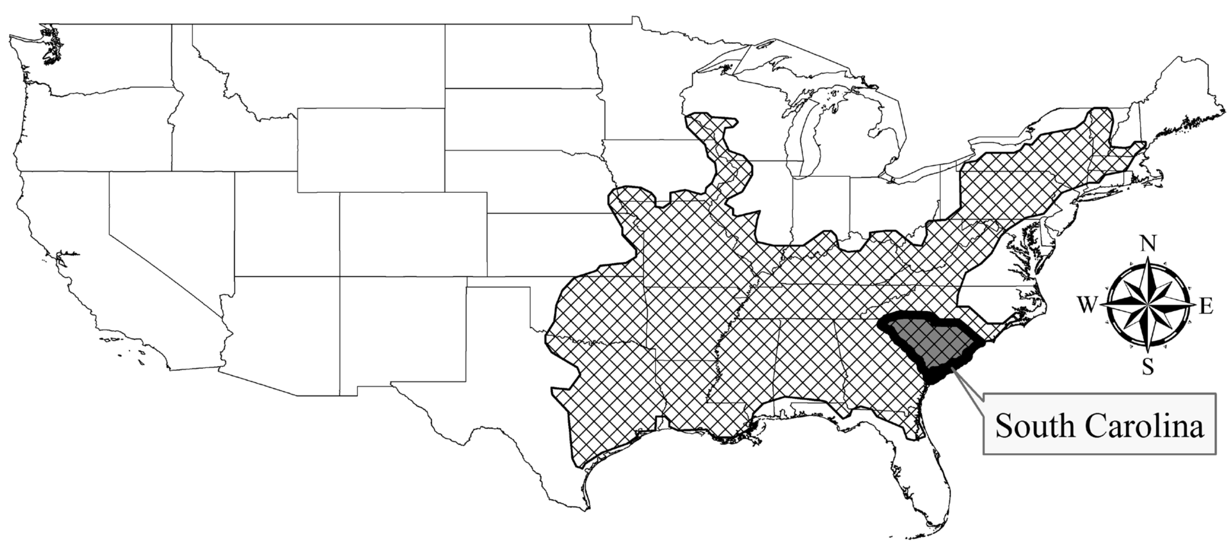

Figure 1. The distribution of the timber rattlesnake, *Crotalus horridus*, in the United States based on Conant and Collins (1998).

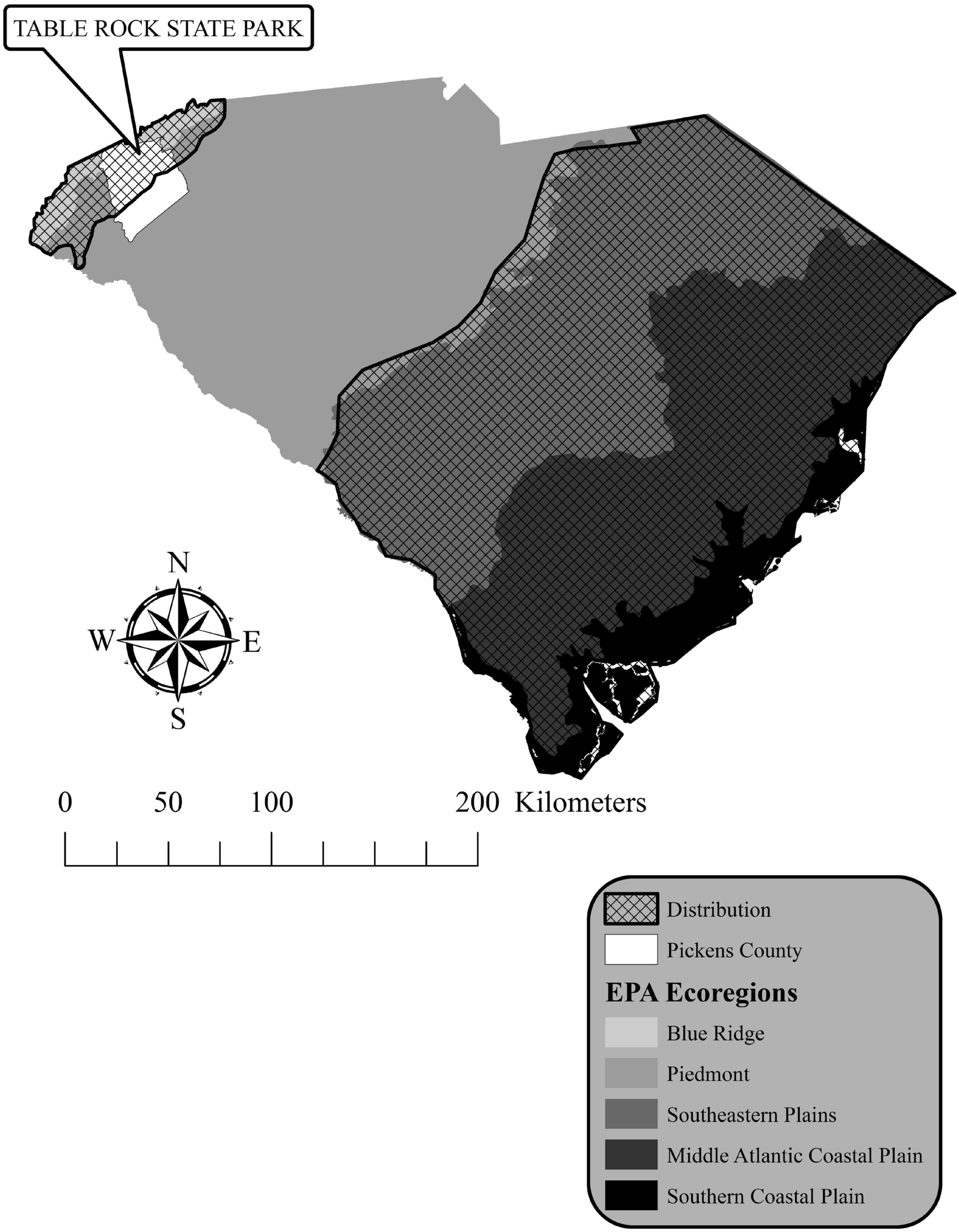

Figure 2. EPA ecoregions of South Carolina and current distribution of the timber rattlesnake, *Crotalus horridus*, based on Martin (1992a:Fig. 1) and SCDNR (2005).

MATERIALS AND METHODS

Natural history observations (e.g., behavior, predation) and general habitat characteristics including tree species dominance, coarse woody debris (e.g., downed trees), leaf litter, rock outcrops, hiking trail proximity, and presence of water in the area in which *Crotalus horridus* were known to occur were documented in field notes. Canopy closure—and subcanopy closure when present—were estimated with a Spherical Crown Densiometer (Forestry Suppliers, Jackson, MS) using random locations (n = 50) within the area where *C. horridus* were known to frequent. Micro-habitat was determined in the field when the rattlesnakes were visually observed. Six micro-habitat categories were employed: less than 1 m from: 1) log/fallen branch, 2) rock, 3) live tree; or in/under: 4) vines/forbs/shrubs, 5) leaf litter; or 6) in the open. If the observation satisfied more than one category, the closest micro-habitat variable to the individual was recorded as primary micro-habitat.

Radio telemetry was used to determine movement patterns from 2006 to 2009 with locating events occurring in March-November of each sample year. During this period, 18 adult *Crotalus horridus* (8 male, 10 female) were fitted with temperature-sensitive radio transmitters (SI-2T and AI-2T transmitter for snakes, Holohil Systems, Ltd., Ontario, Canada). The technique used to implant the transmitter into *C. horridus* closely followed that described by Reinert and Cundall (1982) and Reinert (1992). The mass of the transmitter implanted into each snake did not exceed 5% of the snake's body mass. All surgical procedures were performed at the field laboratory of Table Rock State Park. *Crotalus horridus* locations were fixed using Telonics TR-2 (2006–2007) and TR-4 (2007–2009) receivers and hand-held "H" antennas (Mesa, AZ). Visual verification of *C. horridus* was attempted each time the snake was located using radio telemetry. During the active season (March–November), individual *C. horridus* were located a minimum of twice weekly. Locating events were performed on nonconsecutive days to prevent possible avoidance behavior and locations were recorded in universal transverse mercator (UTM) coordinates using a handheld Global Positioning System (GPS) instrument (Garmin Inc., Olathe, KS) with accuracies < ±4m.

Movements were calculated for *Crotalus horridus* that were successfully tracked for more than one year and/or had greater than 25 unique movement data points ($n = 8$; $n_{male} = 3$, $n_{female} = 5$). I plotted rattlesnake locations using ArcGIS (version 9.3, Environmental Systems Research Institute, Redlands, CA). Due to the fact that male, non-gravid female, and gravid female *Crotalus* spp. can differ in movements (Brown 1982; Reinert & Zappalorti 1988; Timmerman 1995; Marshall et al. 2006; Durbian et al. 2008), snakes were sorted into three categories for analysis: male, non-gravid female, and gravid female. For years in which a female was gravid, movements were treated as unique annual movements. To eliminate outliers and since patterns were often very similar year to year for these sex categories, I calculated the mean annual distance traveled for males and non-gravid females that had multiple year movements. Total annual distance moved was determined by summing the straight line distance between consecutive locations from initial capture (or emergence from hibernacula) until the rattlesnake returned to a winter refuge at the end of the active season (November). Although this method may underestimate true total distance moved by not accounting for deviation from straight line movement paths (Secor 1994); it does provide a standardized measure for comparing movements between individuals and multi-year observations.

One-way analysis of variance (ANOVA) was used to compare the mean movements (total distance and mean distance) of males, non-gravid females, and gravid females and a Tukey-Kramer test was used to determine the significance of the separation of group means. Logistic regression was used to compare percentages of habitat use among the study categories of sex and year as well as for individual *Crotalus horridus*. All statistical analyses were performed using JMP (Version 8.0, SAS Institute, Inc., Cary, NC).

RESULTS

The study area was homogenous oak-hickory deciduous forest with greater than 85% canopy closure except for a few localized small rock outcrops and the major exposed bald rock outcrops. Sub-canopy was sparse throughout the study area except for areas of tree falls or extreme changes in elevation or along infrequent, seasonal riparian areas. Logs and downed trees were available throughout the habitat and leaf litter was uniform throughout much of the habitat likely due to fire suppression in the area for many years. Timber rattlesnakes were associated significantly more with fallen logs/branches than any other micro-habitat type ($F = 22.17$, $df = 5, 136$, $p < 0.0001$). There were no significant differences between sexes ($F = 0.548$, $df = 2, 136$, $p = 0.58$) or years ($F = 1.36$, $df = 2, 127$, $p = 0.26$).

Radio telemetry conducted during 2006–2009 yielded 844 encounters with *Crotalus horridus*. In successive years, individual *C. horridus* utilized the same general areas (i.e., individuals exhibited site fidelity) as illustrated by the examples mapped in Figures 3, 4, and 5. Total distance moved by individual *C. horridus* from egress in the spring (March) to ingress in the fall (November) was not significantly related to sorted categories of sex nor were there significant differences among years ($F = 1.85$, $df = 2$, $p = 0.183$). For the duration of the study, males moved a mean annual distance (± SE) of 3,047 ± 488 m, non-gravid females moved a mean (± SE) of 1,688 ± 517 m, and gravid females moved a mean (± SE) of 2,248 ± 597 m (Table 1).

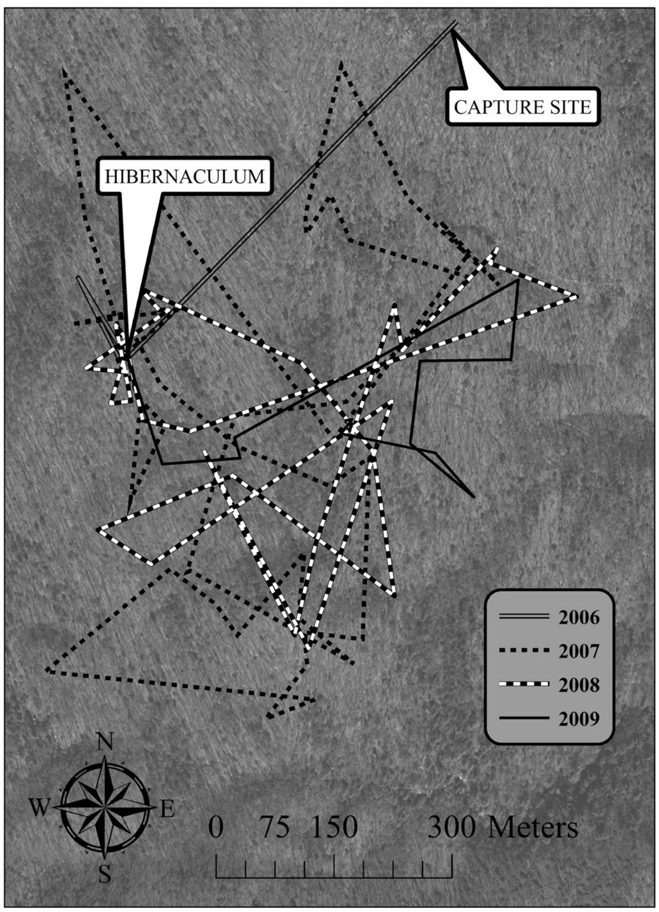

Figure 3. Successive yearly movements of a male timber rattlesnake, *Crotalus horridus*, in Table Rock State Park, Pickens County, South Carolina in 2006 (n = 9), 2007 (n = 58), 2008 (n = 46), and 2009 (n = 23).

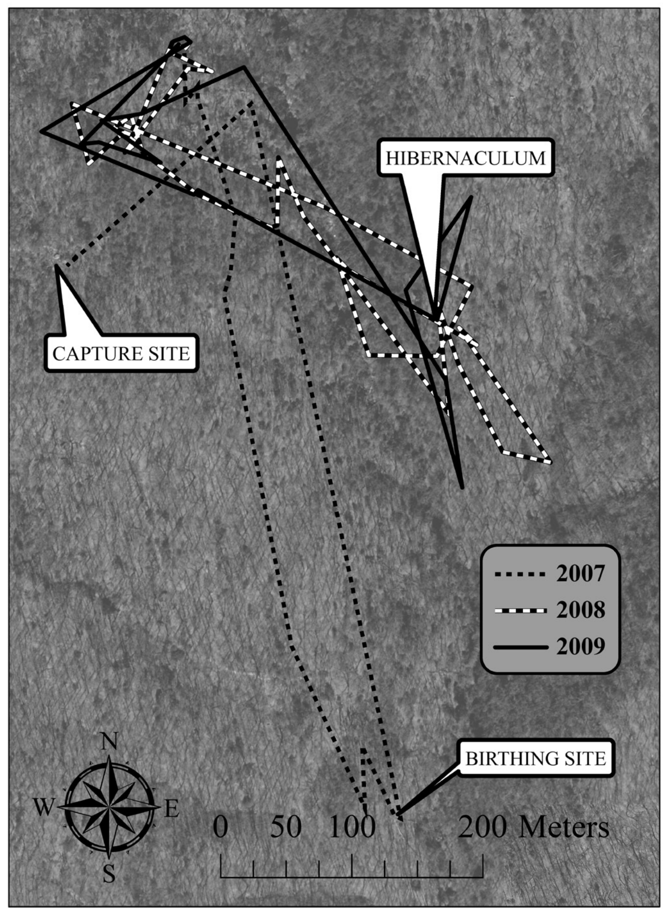

Figure 4. Successive yearly movements of a female timber rattlesnake, *Crotalus horridus*, that was gravid in 2007, in Table Rock State Park, Pickens County, South Carolina in 2007 (n = 30), 2008 (n = 51), and 2009 (n = 33).

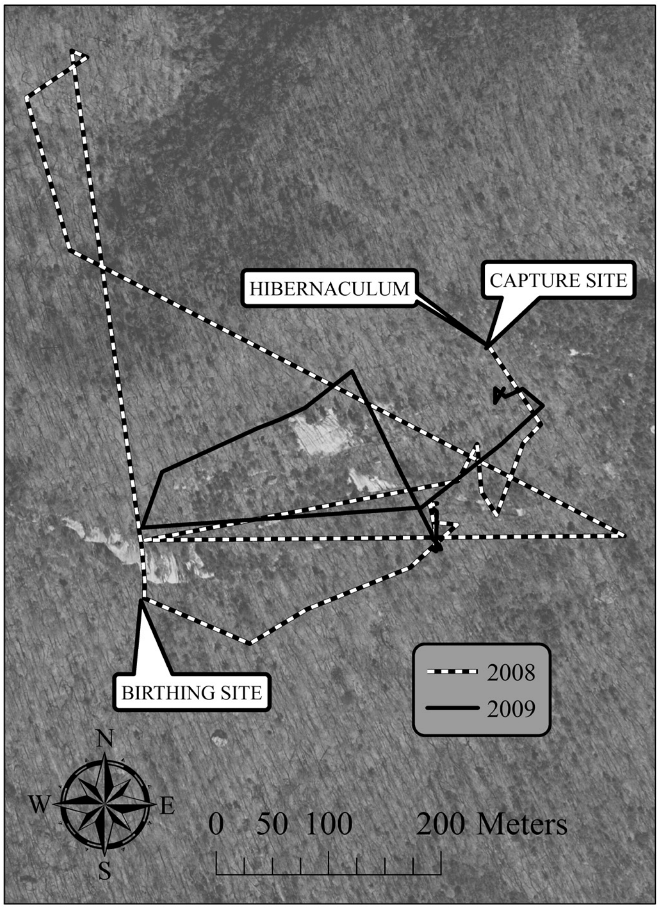

Figure 5. Successive yearly movements of a female timber rattlesnake, *Crotalus horridus,* that was gravid in 2008, in Table Rock State Park, Pickens County, South Carolina in 2008 (n = 38), and 2009 (n = 30).

Table 1. Mean movements (± SE) for all radio-tracked timber rattlesnakes (*Crotalus horridus*) in Table Rock State Park, Pickens County, South Carolina by year and sex.

	Sample Size	Total Distance (m)	Average Distance per movement (m)
Male	8	3047.0 ± 488.1	141.1 ± 10.7*
Female (non-gravid)	8	1687.6 ± 517.7	73.0 ± 11.3
Female (gravid)	6	2248.3 ± 597.8	86.2 ± 13.1
2007	5	3615.6 ± 738.1	120.4 ± 16.9
2008	4	2655.8 ± 825.2	91.0 ± 18.9
2009	6	1691.5 ± 673.8	83.5 ± 15.4

* denotes significance (ANOVA $F = 10.73$, $df = 2$, $p < 0.0007$)

Mean distance (± SE) moved per movement was significantly greater for males (141 ± 11 m) than non-gravid (73 ± 11 m) or gravid females (86 ± 13 m; $F = 10.73$, $df = 2, 19$, $p < 0.0007$; q = 5.8, df = 19, $p < 0.05$).

DISCUSSION

Snakes change locations for a variety of reasons. They will move to a specific habitat to forage (Duvall et al. 1990), to find different microhabitats for thermoregulation (Huey & Peterson 1989), or in search of mates (Duvall & Schuett 1997). In addition to exhibiting inter-annual den site fidelity, other studies found *Crotalus horridus* utilize similar egress routes in the spring and ingress routes in the fall (Brown et al. 1982). Although this pattern of similar egress and ingress routes was not clearly seen in this study, many of the *C. horridus* spent the active season in the same area in consecutive years (Figs. 3–5). This occupation of similar active season home ranges year after year has been observed in other populations of *C. horridus* and *Crotalus* spp. as well (Landreth 1973; Reinert & Zappalorti 1988; Timmerman 1995).

Studies from other populations indicate that male *Crotalus* spp. move farther than females (Timmerman 1995; Reed & Douglas 2002) and *Crotalus horridus* is no exception (Brown 1982; Reinert & Zappalorti 1988; Walker 2000; Gibson 2003). Even though I did not find a significant difference in the mean distance moved among males, non-gravid females, and gravid females, this result is likely an artifact of small sample size. Although not significantly different, but nevertheless in contrast with the existing literature on *C. horridus*, it appeared that gravid females in this study may have had longer movements than non-gravid females (Figs. 4 & 5). As gravid *C. horridus* have been observed to prefer open sites (Keenlyne 1972; Reinert 1984b; Reinert & Zappalorti 1988; Martin 1992b; Fogell et al. 2002; Sealy 2002; Gibson et al. 2008) and open sites are uncommon within the study area, the perceived longer movements of gravid females may be due to the need of these females to travel to find these open areas for enhanced thermoregulation or other physiological requirements. It is also possible, however, gravid females may be dispersing due to other factors such as competition and predation but this has not been investigated in this study. Furthermore, all gravid females gave birth in the year of their surgery and this may have also contributed to abnormal movements.

Most studies involving *Crotalus horridus* indicate two to three times longer total movements for all sexes than was observed in this study (Reinert & Zappalorti 1988; Reinert & Rupert 1999; Gibson 2003; Adams 2005). Possible reasons for the results observed in this study could be the abundance of leaf litter and fallen logs and branches due to a management regime of unmanaged forest regeneration and fire suppression as well as the availability of a large, continuous tract of land. I hypothesize that high levels of leaf litter and debris in the study area, as well as a large tract of undeveloped land, may offer preferred habitat for small mammals—the chief prey item of *C. horridus*. In this study, observed predation events indicated *C. horridus* predated on white-footed mice (*Peromyscus leucopus*), an eastern chipmunk (*Tamias striatus*), and a gray squirrel (*Sciurus carolinensis*), and these species are common prey throughout *C. horridus* range (Clark 2002; Fitch et al. 2004; Reinert et al. 2011). Studies involving *P. leucopus* have indicated decreased numbers in burned areas or areas of little or no woody ground litter (Planz & Kirkland 1992; Kirkland et al. 1996). Rosenblatt et al. (1999) found *T. striatus* and *S. carolinensis* had a preference for large, continuous sites and avoided areas of high habitat fragmentation. Based on personal observation, it appears small mammal density may be high but trapping was not conducted and consequently any comparisons involving small mammal populations and *C. horridus* movement patterns need to be made carefully. Future research in Table Rock State Park will include a study to estimate the densities of potential prey species.

Movement patterns of the different sexes of *C. horridus* observed in this study were similar to those of other populations; however, total movement observed was much less than reported in other studies (Reinert & Zappalorti 1988; Reinert & Rupert 1999; Gibson 2003; Adams 2005). Further research of this and other populations in the southeastern United States would provide a better understanding of *C. horridus* in the southern part of its range. Considering populations of *C. horridus* are declining throughout the species' range (Brown 1993), basic ecological information, such as that presented in this study, is key to creating a viable conservation plan.

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