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Aspects of the Ecology of the Earth Snakes (*Virginia valeriae* and *V. striatula*) in the Upper Coastal Plain

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Abstract - Relatively little is known about the ecology and population biology of *Virginia striatula* (Rough Earth Snake) and *Virginia valeriae* (Smooth Earth Snake), especially in the southeastern portion of their geographic ranges. We studied populations of the two species on the Savannah River Site (SRS) in Aiken, SC from 1971 to 2007. We found sexual size dimorphism in both species, in which females were longer and heavier than males, but had relatively shorter tails. Overall, Rough Earth Snakes were longer and heavier than Smooth Earth Snakes, but maximum sizes of both species were smaller on the SRS than at other localities from which data are reported. Additionally, all gravid female Smooth Earth Snakes that we captured on the SRS were smaller than their reported size at sexual maturity from other parts of their range. Seasonal activity of Smooth Earth Snakes peaked in May and October, but both Smooth Earth Snakes and Rough Earth Snakes were frequently captured during all warm months. Distinct age classes in the two species were not readily apparent other than several neonates that we captured. We strongly encourage future studies to determine growth rates, longevity, and minimum size at sexual maturity of earth snakes in the Southeast.

Introduction

Recent reports of global amphibian and reptile declines have highlighted the contribution of herpetofauna to regional biodiversity and have prompted increased investigation of the functional role of amphibians and reptiles in ecosystems. Although the secretive nature of snakes often makes population estimation difficult (Parker and Plummer 1987), studies have shown that snakes may reach high densities, playing important roles as both predators and prey. For example, Godley (1980) found that *Regina alleni* (Garman) (Striped Crayfish Snake) and *Seminatrix pygaea* (Cope) (Black Swamp Snake) exist at high densities (1200 individuals/ha) in Florida *Eichhornia crassipes* (Mart.) Solms (water hyacinth) communities and estimated that juvenile Striped Crayfish Snakes consume >90% of aquatic odonate larvae annually in that ecosystem. For uncommon or secretive snake species, even basic natural history information (e.g., habitat preferences, diet, activity, growth, and reproduction) remains poorly understood, hampering management and conservation decisions.

Of the 52 snake species found in the southeastern United States, perhaps the most abundant but least studied are small, fossorial "litter

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snakes," including the genera *Carphophis*, *Diadophis*, *Rhadinaea*, *Storeria*, *Tantilla*, and *Virginia* (Willson and Dorcas 2004). Because litter snakes are unsuitable for radio-telemetry and because their secretive habits lead to few recaptures (Semlitsch and Moran 1984; Todd et al., in press; Willson and Dorcas 2004), the ecology and population biology of some species remains unknown, particularly in the Southeast. *Virginia striatula* (Linnaeus) (Rough Earth Snake) and *Virginia valeriae* Baird and Girard (Smooth Earth Snake), are diminutive, natricine snakes which, despite their extensive geographic ranges in the Southeast, are infrequently encountered. Indeed, although the Rough Earth Snake is abundant in western portions of its range (Clark and Fleet 1976, Werler and Dixon 2000) and has served as a model laboratory organism for studies of reproductive allocation and placental morphology in snakes (Stewart 1989, 1990; Stewart and Brasch 2003; Sangha et al. 1996), very little has been published about the natural history of earth snakes in the Southeast.

The Savannah River Site (SRS), an 803-km^2 US Department of Energy facility located in the Upper Coastal Plain of South Carolina, has been the focus of intense herpetological research since 1951 (Gibbons et al. 1997). Since establishment, researchers have amassed a database of over 25,000 records of the 36 snake species found on the SRS. This extensive database permits study of species that are usually too secretive or uncommon to be the focus of directed research. Here, we use this database to examine various aspects of the natural history of the earth snakes in the Southeast. Specifically, we examine morphology (body size and sexual size dimorphism), abundance and seasonal activity, reproduction, and population demography of these uncommon and secretive species.

Methods

Study site

The Savannah River Site (SRS) was established in 1951 in Aiken, Barnwell, and Allendale counties in South Carolina. The site, protected from extensive anthropogenic disturbance and development since 1951, generally comprises managed pine forests and second-growth hardwood habitats, but supported agriculture prior to federal establishment (Gibbons et al. 2006).

Data collection and analysis

Although earth snakes are apparently less common than some other small snakes (e.g., *Tantilla coronata* Baird and Girard [Southeastern Crowned Snake]; Todd et al. 2008), Rough Earth Snakes and Smooth Earth Snakes are encountered fairly frequently during herpetological research on the SRS. We captured earth snakes on the SRS from 1971 to 2007 using coverboards (e.g., Grant et al. 1992), drift fences with pitfall traps (Gibbons and Semlitsch 1982), and by turning natural cover objects during active searches. Recent

studies (2004–2007) using extensive drift fence and pitfall trapping have generated considerable captures of Smooth Earth Snakes on the SRS (Todd and Andrews 2008, Todd and Rothermel 2006). In general, we measured the mass (nearest mg), snout–vent length (SVL; nearest mm), and tail length (nearest mm) of field-captured animals in the laboratory. We determined the sex of individuals by manual eversion of the hemipenes, cloacal probing, or dissection (for any animals that died in the field or during transport), and in some cases, we palpated females to note the presence and number of follicles or developing embryos. Marking effort varied from 1971–2007, but we did mark many earth snakes by clipping ventral scales or by heat branding ventral and lateral scales (Winne et al. 2006).

We used two-way analyses of variance to test for effects of sex and species on the SVL and mass of captured animals, excluding any intra-year recaptures from analyses. We used a two-way analysis of covariance to test for effects of sex and species on relative tail length, using SVL as a covariate and excluding from analysis any intra-year recaptures and any animals that had shortened tails due to injury. We log-transformed all data prior to analyses to ensure that statistical assumptions were met (King et al. 1999).

To examine seasonal activity of Smooth Earth Snakes, we used data collected from a recent intensive pitfall trapping study with known trapping effort (Todd and Andrews, in press; Todd and Rothermel 2006), which allowed us to adjust monthly captures for trapping effort and eliminate effort-related sampling biases. Specifically, we divided monthly captures by the number of total trap nights in each month. We used chi-square tests for each month from 1971–2007 in which sample sizes were large enough to determine whether monthly captures of Smooth Earth Snakes were sex-biased. Additionally, we used all SRS data for both Smooth Earth Snakes and Rough Earth Snakes to examine demographic structure by plotting the SVL of captured animals according to their date of capture.

Results

From 1971–2007, we captured 222 Smooth Earth Snakes and 40 Rough Earth Snakes on the SRS. For some older captures, morphological data, sex, and/or the completeness of the tails were not always recorded, rendering some measurements unusable in analyses. Overall, Rough Earth Snakes were significantly longer ($F_{1,92} = 42.1$, $p < 0.001$) and significantly heavier than Smooth Earth Snakes ($F_{1,82} = 19.9$, $p < 0.001$; Table 1). For both species, females were significantly longer ($F_{1,92} = 22.3$, $p < 0.001$) and heavier ($F_{1,82} = 11.0$, $p = 0.001$) than males (Table 1). When we analyzed tail lengths, we found a significant interaction between sex and species ($F_{1,91} = 6.1$, $p = 0.016$). Subsequent one-way analyses of covariance indicated that relative tail lengths of males and females differed significantly in Smooth Earth

Snakes, but were only marginally different in Rough Earth Snakes (Smooth Earth Snake: $F_{1,71} = 56.6$, $p < 0.001$; Rough Earth Snake: $F_{1,19} = 4.0$, $p = 0.06$; Table 1). Interaction terms for all other analyses were non-significant (SVL: $F_{1,92} = 2.6$, $p = 0.11$; Mass: $F_{1,82} = 2.8$, $p = 0.10$).

Generally, Smooth Earth Snakes were most active during warmer months of the year compared to colder months (Fig. 1). However, captures in pitfall traps were greatest in May and October (Fig. 1). Although no Smooth Earth Snakes were captured in pitfall traps in January or February during an intensive study from 2004–2006, they have been captured on the SRS in pitfall traps during all months of the year in other years. The earliest recorded capture in a year of an active Smooth Earth Snake was 19 January 2001, and the latest was 1 December 2004. Too few Rough Earth Snakes were captured to determine seasonal activity patterns, but most captures from 1971–2007 were recorded in the spring and fall. The earliest recorded capture of a Rough Earth Snake

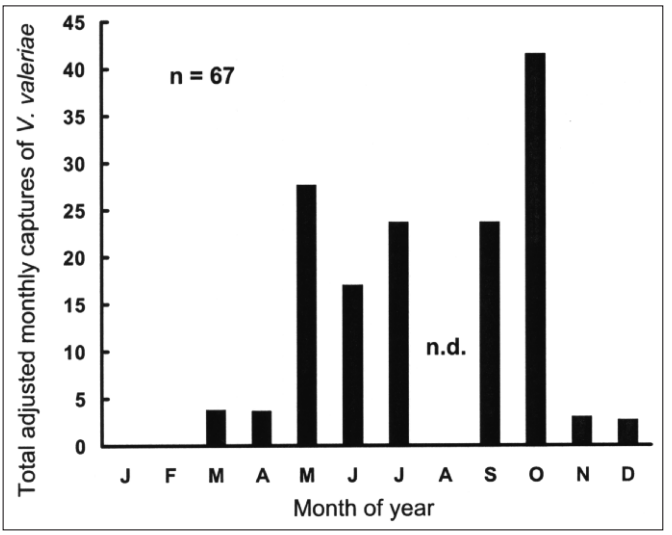

Figure 1. Monthly relative abundance of *Virginia valeriae* (Smooth Earth Snakes) captured during intensive pitfall trapping from 2004–2006 at four locations on the Savannah River Site, Aiken, SC. Captures are adjusted for sampling effort by dividing total monthly captures by trap nights for that month and multiplying by 10^6. "n.d." indicates that no data were collected in August from 2004–2006.

Table 1. Mean body sizes of *Virginia valeriae* (Smooth Earth Snake) and *V. striatula* (Rough Earth Snake) captured from 1971–2007 on the Savannah River Site, Aiken, SC.

	Mass (g)		Snout–vent length (mm)		Tail length (mm)		Tail length/ total length (%)
Species	Mean (range)	n	Mean (range)	n	Mean (range)	n	Mean (range)
Virginia valeriae							
Male	1.97 (0.9–3.1)	40	138.5 (103–174)	43	30.3 (11–41)	43	17.9 (8.9–21.7)
Female	3.37 (1.3–6.4)	29	173.6 (119–222)	31	25.0 (8–37)	31	12.6 (5.4 –15.4)
Virginia striatula							
Male	3.5 (2.5–5.6)	9	184.4 (151–209)	13	41.6 (23–52)	13	22.6 (13.6–26.0)
Female	4.3 (2.4–6.7)	8	204.9 (174–256)	9	38.2 (29–49)	9	18.8 (13.6–24.2)

was 9 March 2004, and the latest recorded capture occurred on 12 November 1985. Captures of Smooth Earth Snakes were sex-biased in favor of females in April ($\chi^2 = 6.7$, $p = 0.01$), but were sex-biased in favor of males in August ($\chi^2 = 5.4$, $p = 0.02$; Fig. 2).

We recaptured one female Smooth Earth Snake initially captured in the fall of 2006 and recaptured twice in the spring and early summer of 2007. Although she had not increased in length, her body mass had increased from 3.98 g to 5.84 g and she had developed 4 large embryos. One male Rough Earth Snake was recaptured over a one-month interval in spring of 1985 with no change in size. No other individually marked snakes were ever resighted.

In both species, neonates were easily distinguishable from other age classes in the populations (Smooth Earth Snake: Fig. 3; Rough Earth Snake: Fig. 4). However, animals entering their second calendar year of life (i.e., reaching one year of life) and older could not easily be assigned to any particular age class (Figs. 3, 4). From 1971–2007, six gravid Smooth Earth Snakes measuring 155–181 mm SVL were captured between March 30–July 17 with clutch sizes ranging from 3–6 embryos (mean = 4.2).

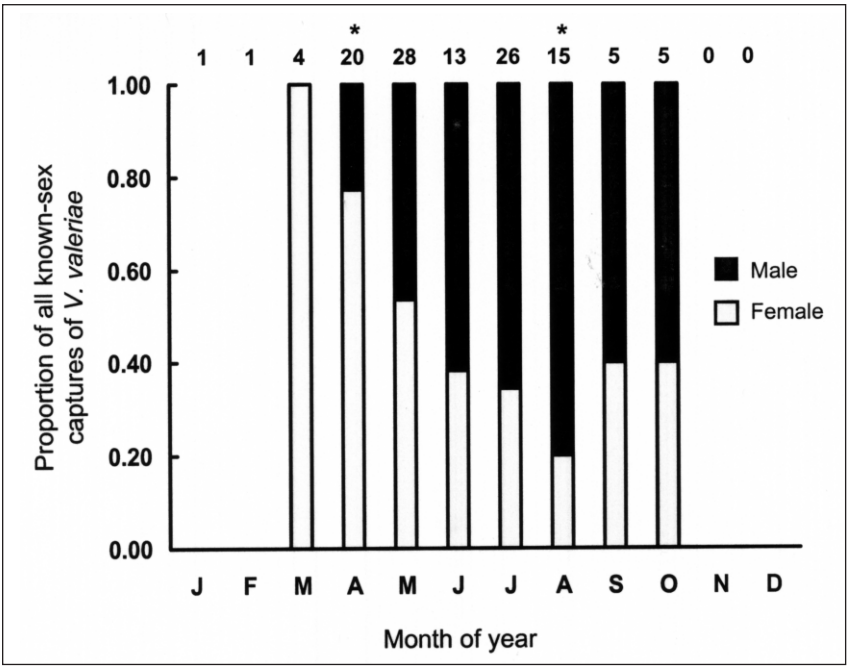

Figure 2. Monthly sex ratios of *Virginia valeriae* (Smooth Earth Snakes) captured from 1971 –2007 on the Savannah River Site, Aiken, SC. Sample sizes of known-sex animals are listed above the bars. An asterisk "*" denotes a significant sex bias in captures for a given month.

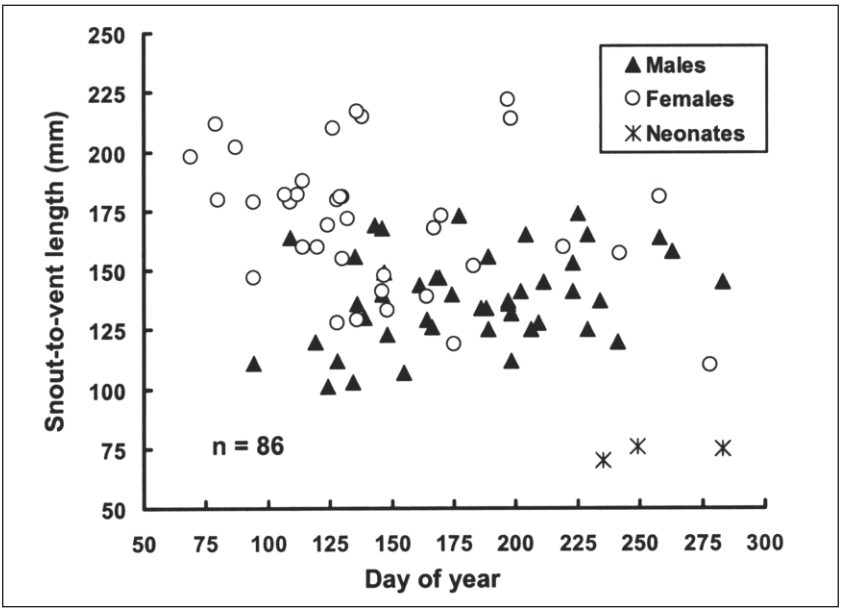

Figure 3. Snout-to-vent length versus julian day of capture for *Virginia valeriae* (Smooth Earth Snakes) captured from 1971–2007 on the Savannah River Site, Aiken, SC.

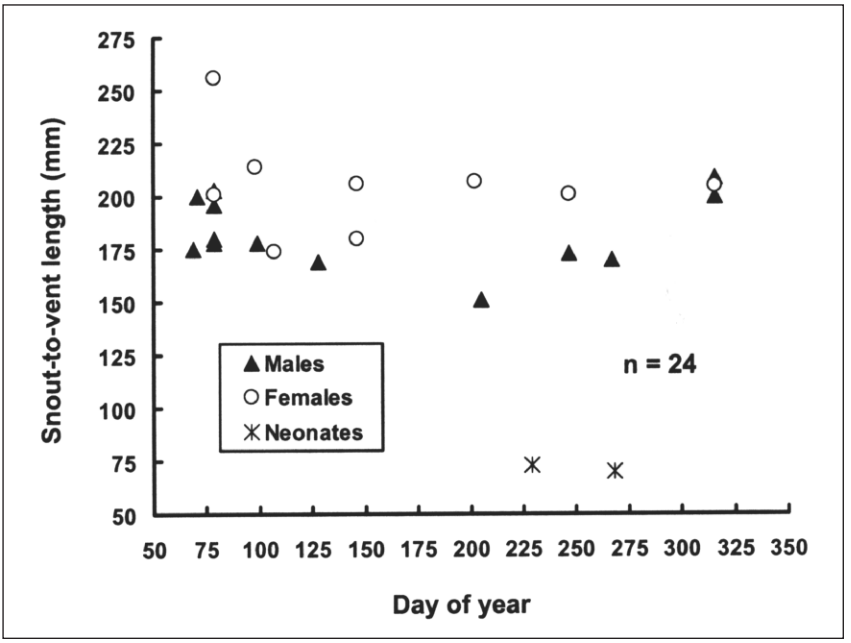

Figure 4. Snout-to-vent length versus julian day of capture for *Virginia striatula* (Rough Earth Snakes) captured from 1971–2007 on the Savannah River Site, Aiken, SC.

Discussion

We found evidence of sexual size dimorphism in Smooth Earth Snakes and Rough Earth Snakes that is generally consistent with observations of other North American colubrid snakes (Kaufman and Gibbons 1975, King 1989). Specifically, females tended to be larger and heavier than males but had relatively shorter tails. Also, our observation that Rough Earth Snakes were larger than Smooth Earth Snakes is consistent with other reports of the species from elsewhere in their ranges (summarized in Ernst and Ernst 2003). Interestingly, samples of both species captured on the SRS were smaller than those collected in at least one other part of their range. For example, Palmer and Braswell (1995) report the five longest males (Rough Earth Snake: 212–220 mm; Smooth Earth Snake: 189–199 mm) and females (Rough Earth Snake: 239–268 mm; Smooth Earth Snake: 209–242 mm) of both species captured across North Carolina, all but one of which were larger than the five largest males and females of both species captured on the SRS (see Table 1 for size ranges).

Like all North American natricine snakes, the earth snakes are viviparous. Birthing of neonates reportedly occurs from the end of June through September, and the young measure 64–123 mm SVL in Smooth Earth Snakes and 74–127 mm SVL in Rough Earth Snakes (Ernst and Ernst 2003). Neonates of both species on the SRS were recognizable from other cohorts by their small size, and the timing of their capture was consistent with reported birthing dates. However, larger earth snakes on the SRS did not readily fall into distinguishable age classes. The shortest sexually mature male Smooth Earth Snake reported by Mitchell (1994) was captured in Virginia at an SVL of 153 mm. The shortest pregnant Smooth Earth Snakes reported were 183 and 185 mm SVL (Blem and Blem 1985, Mitchell 1994), also in Virginia. All pregnant Smooth Earth Snakes that we captured on the SRS were smaller than pregnant females reported from elsewhere in their range, suggesting that Smooth Earth Snakes reach reproductive maturity at a smaller size on the SRS than in other parts of their range. This finding coincides with the generally smaller body sizes of earth snakes on the SRS compared with other populations.

Both Smooth Earth Snakes and Rough Earth Snakes are described as being most active from April to November (Ernst and Ernst 2003). Additionally, Palmer and Braswell (1995) and Gibbons and Semlitsch (1987) report bimodal seasonal activity patterns for Smooth Earth Snakes in the Southeast; our results are generally consistent with these earlier findings. Smooth Earth Snakes on the SRS were most active in May and October, but were also frequently captured in all warm months, as were Rough Earth Snakes. Male-biased captures of Smooth Earth Snakes in August suggest that this species may breed in the late summer to early fall, as has been suggested for other small southeastern snakes such as *Carphophis amoenus* (Say) (Eastern

Wormsnake) (Russell and Hanlin 1999, Willson and Dorcas 2004) and Southeastern Crowned Snakes (Aldridge and Semlitsch 1982; Todd et al., in press). Female-biased captures of Smooth Earth Snakes in the spring may be a result of increased foraging by females as they prepare for reproduction following several cooler months of reduced activity.

Small-bodied snakes are generally under-represented in scientific literature, possibly because their secretive habits often preclude the capture of adequate numbers of them for study. As a result, little is known about the ecology and natural history of many small-bodied snakes. Although our study provides insight into the ecology and life history of two species of earth snakes in the Southeast, we strongly encourage additional study to elucidate the ecology of small snakes, both in the Southeast and throughout their ranges.

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Literature Cited

Aldridge, R.D., and R.D. Semlitsch. 1982. Male reproductive biology of the Southeastern Crowned Snake (*Tantilla coronata)*. Amphibia-Reptilia 13:219–225.

Blem, C.R., and L.B. Blem. 1985. Notes on *Virginia* (Reptilia: Colubridae) in Virginia. Brimleyana 11:87–95.

Clark, D.R., Jr., and R.R. Fleet. 1976. The Rough Earth Snake (*Virginia striatula*): Ecology of a Texas population. Southwestern Naturalist 20:467–478.

Ernst, C.H., and E.M. Ernst. 2003. Snakes of the United States and Canada. Smithsonian Press, Washington, DC.

Gibbons, J.W., and R.D. Semlitsch.1982. Terrestrial drift fences with pitfall traps: An effective technique for quantitative sampling of animal populations. Brimleyana 1982(7):1–16.

Gibbons, J.W., and R.D. Semlitsch. 1987. Activity patterns. Pp. 396–421, *In* R.A. Seigel, J.T. Collins, and S.S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology. MacMilllan Publishing Co., New York, NY.

Gibbons, J.W., V.J. Burke, J.E. Lovich, R.D. Semlitsch, T.D. Tuberville, J.R. Bodie, J.L. Greene, P.H. Niewiarowski, H.H. Whiteman, D.E. Scott, J.H.K. Pechmann, C.R. Harrison, S.H. Bennett, J.D. Krenz, M.S. Mills, K.A. Buhlmann, J.R. Lee,

R.A. Seigel, A.D. Tucker, T.M. Mills, T. Lamb, M. E. Dorcas, J.D. Congdon, M.H. Smith, D.H. Nelson, M.B. Dietsch, H.H. Hanlin, J.A. Ott, and D.J. Karapatakis. 1997. Perceptions of species abundance, distribution, and diversity: Lessons from four decades of sampling on a government-managed reserve. Environmental Management 21:259–268.

Gibbons, J.W., C.T. Winne, D.E. Scott, J.D. Willson, X. Glaudas, K.M. Andrews, B.D. Todd, L. A. Fedewa, L. Wilkinson, R.N. Tsaliagos, S.J. Harper, J.L. Greene, T.D. Tuberville, B.S. Metts, M.E. Dorcas, J.P. Nestor, C.A. Young, T. Akre, R.N. Reed, K.A. Buhlmann, J. Norman, D.A. Croshaw, C. Hagen, and B.B. Rothermel. 2006. Remarkable amphibian biomass and abundance in an isolated wetland: Implications for wetland conservation. Conservation Biology 20:1457–1465.

Godley, J.S. 1980. Foraging ecology of the Striped Swamp Snake, *Regina alleni*, in Southern Florida. Ecological Monographs 50:411–436.

Grant, B.W., A.D. Tucker, J.E. Lovich, A.M. Mills, P.M. Dixon, and J.W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pp.379–403, *In* D.R. McCullough and R.H. Barrett (Eds.). Wildlife 2001. Elsevier Science Publishing, Inc., London, UK.

Kaufman, G.A., and J.W. Gibbons. 1975. Weight-length relationships in thirteen species of snakes in the southeastern United States. Herpetologica 31:31–37.

King, R.B. 1989. Sexual dimorphism in snake tail length: Sexual selection, natural selection, or morphological constraint? Biological Journal of the Linnaean Society 38:133–154

King, R.B., T.D. Bittner, A. Queral-Regil, and J.H. Cline. 1999. Sexual dimorphism in neonate and adult snakes. Journal of Zoology, London 247:19–28.

Mitchell, J.C. 1994. The Reptiles of Virginia. Smithsonian Institution Press, Washington, DC.

Palmer, W.M., and A.L. Braswell. 1995. Reptiles of North Carolina. University of North Carolina Press, Chapel Hill, NC.

Parker, W.S., and M.V. Plummer. 1987. Population ecology. Pp. 253–301, *In* R.A. Seigel, J.T. Collins and S.S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology, McGraw-Hill, Inc., New York, NY.

Russell, K.R., and H.G. Hanlin. 1999. Aspects of the ecology of Worm Snakes (*Carphophis amoenus*) associated with small isolated wetlands in South Carolina. Journal of Herpetology 33:344–348.

Sangha, S., M.A. Smola, S.L. McKinney, D.R. Crotzer, C.A. Shadrix, and J.R. Stewart. 1996. The effect of surgical removal of oviductal eggs on placental function and size of neonates in the viviparous snake *Virginia striatula*. Herpetologica 52:32–36.

Semlitsch, R.D., and G.B. Moran. 1984. Ecology of the Redbelly Snake (*Storeria occipitomaculata*) using mesic habitats in South Carolina. American Midland Naturalist 111:33–40.

Stewart, J.R. 1989. Facultative placentotrophy and the evolution of squamate placentation: Quality of eggs and neonates in *Virginia striatula*. American Naturalist 133:111–137.

Stewart, J.R. 1990. Development of the extraembryonic membranes and histology of the placentae in *Virginia striatula* (Squamata, Serpentes). Journal of Morphology 205:33–43.

Stewart, J.R., and K.R. Brasch. 2003. Ultrastructure of the placentae of the natricine snake, *Virginia striatula* (Reptilia: Squamata). Journal of Morphology 255: 177–201.

Todd, B.D., and K.M. Andrews. In Press. Response of a reptile guild to forest harvesting. Conservation Biology.

Todd, B.D., and B.B. Rothermel. 2006. Assessing quality of clearcut habitats for amphibians: Effects on southern toad abundances versus vital rates. Biological Conservation 133(2):178–185.

Todd, B.D., J.D. Willson, C.T. Winne, R.D. Semlitsch, and J.W. Gibbons. In Press. Ecology of the Southeastern Crowned Snake, *Tantilla coronata*. Copeia.

Werler, J.E., and J.R. Dixon. 2000. Texas Snakes: Identification, Distribution, and Natural History. University of Texas Press, Austin, TX.

Willson, J.D., and M.E. Dorcas. 2004. Aspects of the ecology of small fossorial snakes in the western Piedmont of North Carolina. Southeastern Naturalist 3:1–12.

Winne, C.T., J.D. Willson, K.M. Andrews, and R.N. Reed. 2006. Efficacy of marking snakes with disposable medical cautery units. Herpetological Review 37:52–54.