ASPECTS OF THE ECOLOGY OF SMALL FOSSORIAL SNAKES IN THE WESTERN PIEDMONT OF NORTH CAROLINA

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ABSTRACT - In many areas, small fossorial snakes are among the most abundant vertebrates present; yet, the ecology of these species remains poorly understood. Between 1999 and 2002 we collected 210 small fossorial snakes representing five species in a small area of northern Mecklenburg and southern Iredell Counties, North Carolina. The eastern worm snake (*Carphophis amoenus*; n = 116) was the most frequently captured species in this region, with fewer numbers of ringneck snakes (*Diadophis punctatus*; n = 44), brown snakes (*Storeria dekayi*; n = 24), redbellied snakes (*S. occipitomaculata*; n = 20), and smooth earth snakes (*Virginia valeriae*; n = 6). The three most abundant species exhibited significant sexual dimorphism, with females being larger and having shorter relative tail lengths than males. *Carphophis amoenus* were more abundant in dry upland forest than *D. punctatus*, which were most prevalent in moist, lowland forest. Snake activity was weakly correlated with environmental conditions. A peak in activity of male *C. amoenus*, *D. punctatus*, and *S. occipitomaculata* during September suggests fall breeding seasons for these species.

INTRODUCTION

Snakes can be important, though under-appreciated, components of many ecosystems. In some areas, small snakes occur in extraordinarily high densities, composing a large portion of the vertebrate biomass and playing important roles as both predators and prey. For example, Fitch (1975) estimated densities of ringneck snakes (*Diadophis punctatus*) at greater than 1000 per ha in Kansas, and Godley (1980) reported average densities of greater than 1200 striped crayfish snakes (*Regina alleni*) and black swamp snakes (*Seminatrix pygaea*) per ha in Florida water hyacinth communities.

The western Piedmont of North Carolina supports several species of small fossorial snakes that can often be found in high densities. The worm snake (*Carphophis amoenus*), ringneck snake (*D. punctatus*), brown snake (*Storeria dekayi*), redbellied snake (*S. occipitomaculata*), and smooth earth snake (*Virginia valeriae*) all have extensive ranges in the eastern United States and in many areas can be quite common. Nevertheless, detailed studies of the ecology of these species are few (but see Brodie and Ducey 1989; Clark 1970; Fitch 1975, 1999; Russell

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and Hanlin 1999; Semlitsch and Moran 1984) and none have been conducted in the Piedmont region of the Southeastern United States.

We examined the natural history of five species of small fossorial snakes in the western Piedmont of North Carolina based on four years of fieldwork using a variety of collecting techniques. We present information on relative abundances, habitat use, seasonal activity patterns, morphology, and limited data on reproduction and diet for these species.

Study area

This study was conducted in southwestern Piedmont of North Carolina, in Mecklenburg and Iredell Counties. The majority of snakes were collected from the Davidson College Ecological Preserve (DCEP), an 89-ha tract of forested land adjacent to the Davidson College Campus. The DCEP is predominantly comprised of second-growth mixed hardwood-pine forest and contains several small streams, sections of old field habitat, and power line right-of-ways. A limited number of the snakes included in this study were collected from similar habitats within 8 km of the DCEP.

METHODS

Snakes were collected over a four-year period (1999–2002) using terrestrial drift fences with pitfall traps (Gibbons and Semlitsch 1982), coverboard arrays (Grant et al. 1992), and incidental hand captures. Two 150-m drift fences (A and B), each with 30 75-cm deep pitfall traps, were installed during the spring of 1999 in mixed pine-hardwood forest of the DCEP. Drift fence A was located in dry upland forest, about 150 m from a small stream. Drift Fence B was located in damp forest at the edge of the stream floodplain, approximately 100-m away and downhill from drift fence A. Drift-fence pitfalls were opened and checked daily from 20 April–12 July 1999; 22 February–12 May and 1 September–27 October 2000; 2 February–1 May, 12 September–6 November 2001, and 4 April–12 May 2002; for a total of 23,940 trap-nights. Coverboards (61 x 122 x 1.1-cm plywood; n = 110) were set in three arrays (mixed forest, old field edge, and power line right of way) on the DCEP in spring 1999. Boards were checked several times per week during warm weather between 1999 and 2002. Additionally, snakes were opportunistically collected under other natural and artificial cover objects and when incidentally encountered.

All snakes were returned to the laboratory where they were sexed by probing, measured (snout-vent length [SVL] and tail length to the nearest mm), weighed to the nearest 0.1 gram, and released at their capture location within three days. Snakes were manually palpated for the presence of food items, eggs, or embryos. However, likely due to the small size and soft bodies of typical prey for these species (e.g. earthworms) few food items were identified in this way. Initially, large *C. amoenus* and *D. punctatus* were marked by pit-tagging (Russel and Hanlin 1999), however we discontinued this process after several months out of concern that we were causing undo injury to snakes. As we had no recaptures of marked snakes and other studies on these species have reported low recapture rates (Russel and Hanlin 1999, Semlitsch and Moran 1984), we decided that impacts of pseudoreplication on our results were minimal.

Comparisons of capture proportions of *C. amoenus* and *D. punctatus* between the two drift fences were made using a χ^2 test and between drift fence A and coverboards in the same habitat using a Fishers Exact Test. Snake activity was assessed using Poisson regression (SAS 2000; alpha = 0.05) to correlate weekly snake captures in drift fences with weekly precipitation, weekly average maximum air temperature, and weekly average minimum air temperature. Climatic data was obtained for Concord, NC (about 25 km from Davidson) from the National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html; accessed March 2003). Seasonal snake activity was assessed using monthly drift fence capture rates (determined by dividing the number of snakes captured in each month by the number of days that pitfalls were open during that month).

We set the size of sexual maturity at 170 mm SVL for both sexes of *C. amoenus* (Palmer and Braswell 1995, Russel and Hanlin 1999), 180 mm SVL for male and 218 mm SVL for female *D. punctatus* (Mitchell 1994), 150 mm SVL for male and 175 mm SVL for female *S. dekayi* (Mitchell 1994), 118 mm SVL for male and 126 mm SVL for female *S. occipitomaculata* (Semlitsch and Moran 1984), and 125 mm for male and 185 mm SVL for female *V. valeriae* (Blem and Blem 1985). Morphological comparisons were made using single-factor ANOVA (JMP; Sall and Lehman 1996). We assessed sexual dimorphism in body shape in *C. amoenus* and *D. punctatus* by comparing the residuals from a regression of mass on SVL (both variables log-transformed prior to regression) using ANOVA (Shine et al. 2002). Alpha was set at 0.05, and ratios (i.e., tail length / total length) were arcsin square-root transformed before statistical analysis.

RESULTS

Between 1999 and 2002 we collected 210 small fossorial snakes of five species (Table 1). The most common snake encountered was the eastern worm snake (*C. amoenus*; n = 116). The second most commonly encountered species was the ringneck snake (*D. punctatus*; n = 44), the majority of which were captured in terrestrial drift fences. The three least frequently encountered species in our study area were the brown snake (*S. dekayi*; n = 24), redbellied snake (*S. occipitomaculata*; n = 20), and the smooth earth snake (*V. valeriae*; n = 6).

Table 1. Capture numbers and morphological characteristics of five species of small fossorial snakes in northern Mecklenburg and southern Iredell Counties, North Carolina. Capture methods are abbreviated: DF = drift fence with pitfall traps, CB = plywood coverboard, HC = incidental hand capture. Asterisks represent significant differences between males and females of a given species when compared using single-factor ANOVA ($\alpha = 0.05$).

		Capture method			Snout-vent length (mm)	Tail length (mm)	Tail length/total length	Mass (g)
	N	DF	CB	HC	mean (range)	mean (range)	mean (range)	mean (range)
Carphophis amoenus	116	27	51	38				
Male	46	11	18	17	211.2 (170–244)*	44.8 (24–67)*	17.4 (12.0–21.5)*	5.6 (3.1–8.4)*
Female	34	8	20	6	230.4 (190–262)*	34.0 (24–43)*	12.9 (10.4–16.3)*	7.2 (4.2–10.7)*
Juvenile	36	8	13	15	126.6 (90–168)	23.1 (9–46)	15.0 (6.4–30.7)	1.6 (0.6–3.2)
Diadophis punctatus	44	24	7	13				
Male	17	10	1	6	243.9 (182–295)*	63.8 (46–78)	20.9 (18.1–23.2)*	6.7 (3.0–11.3)*
Female	13	7	2	4	277.1 (240–371)*	62.7 (45–80)	18.6 (10.8–22.9)*	8.9 (5.2–17.1)*
Juvenile	14	7	4	3	151.4 (80–215)	36.2 (21–54)	19.5 (12.6–26.1)	3.4 (0.8–7.1)
Storeria dekayi	24	3	6	15				
Male	6	2	1	3	225.7 (157–274)	68.8 (42–88)	23.2 (21.1–24.3)*	5.1 (2.1–6.5)*
Female	9	1	1	7	245.1 (186–288)	55.8 (22–78)	18.5 (10.4–22.2)*	9.5 (2.7–13.3)*
Juvenile	9	0	4	5	143.4 (128–149)	36.5 (24–52)	19.9 (14.6–25.5)	1.97 (0.8–3.6)
S. occipitomaculata	20	13	3	4				
Male	8	5	2	1	160.6 (125–190)	44.8 (39–60)	21.7 (13.2–26.1)	2.4 (1.3–3.9)
Female	7	4	1	2	181.8 (144–209)	48.8 (37–55)	21.1 (20.3–22.8)	3.0 (1.4–4.3)
Juvenile	5	4	0	1	114.0 (112–116)	30.0 (23–37)	20.7 (16.7–24.7)	0.8 (0.6–0.9)
Virginia valeriae	6	1	3	2				
Male	1	0	1	0	190.0	41.0	17.7	5.3
Female	4	1	1	2	211.7 (206–219)	27.3 (22–30)	11.4 (9.1–12.5)	9.3 (8.9–9.6)
Juvenile	1	0	1	0	119.0	16.0	11.9	

A significantly greater proportion of *C. amoenus* relative to *D. punctatus* were captured in drift fence A than in drift fence B (Fig. 1; $\chi^2 = 5.12$, $p = 0.028$). Additionally, a greater proportion of *D. punctatus* relative to *C. amoenus* were captured in drift fence A than under coverboards nearby in the same habitat (Fig. 1; Fisher's Exact Test, $p = 0.048$).

Snake activity peaked in the fall, particularly in September (Fig. 2A). In *C. amoenus*, *D. punctatus* and *S. occipitomaculata* this peak was primarily comprised of adult male snakes (Fig. 2B, C, and D). Poisson regression using weekly snake captures and environmental variables revealed that only weekly average minimum temperature was significantly correlated with weekly snake captures ($P = 0.001$). However, examination of residuals suggested that this model is a very poor fit for these data. The residuals showed a pattern of increasing magnitude with increasing number of captures.

Carphophis amoenus exhibited a bimodal size frequency distribution with peaks between 90 and 105 mm and between 165 and 210 mm SVL (Fig. 3A). Young *C. amoenus* were distinguishable in size from adults during their first year, apparently growing from about 95 to 170 mm SVL during their first full season of growth (Fig. 4). In *D. punctatus* there was also a peak in captures representing young individuals (Fig. 3B). However, the size frequency distribution of *D. punctatus* was generally more unimodal in appearance than that of *C. amoenus*.

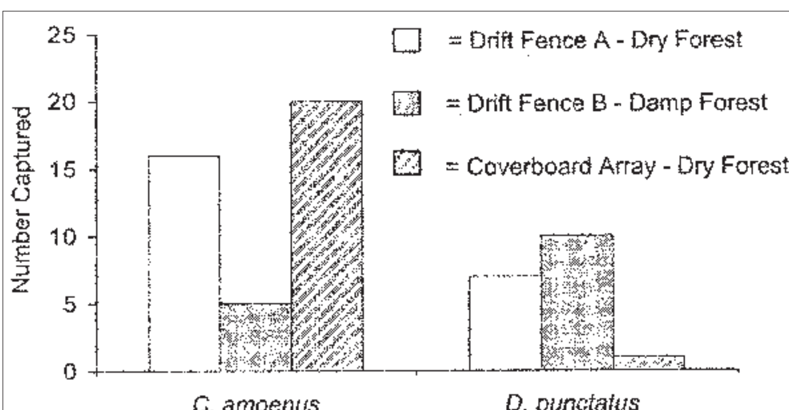

Figure 1. Differential captures of *Carphophis amoenus* and *Diadophis punctatus* in two terrestrial drift fences and one coverborad array on the Davidson College Ecological Preserve. Drift fence A was located in dry, upland, mixed pine-hardwood forest. Drift fence B was located slightly lower in elevation along the floodplain of a small creek in damp mixed pine-hardwood forest. The coverboard array was located < 50 m from drift fence A in the same habitat. Relative capture rates of *C. amoenus* and *D. punctatus* were significantly different between drift fence A and B ($\chi^2 = 5.12$, $p = 0.028$) and between drift fence A and coverboard array (Fishers Exact Test, $p = 0.048$).

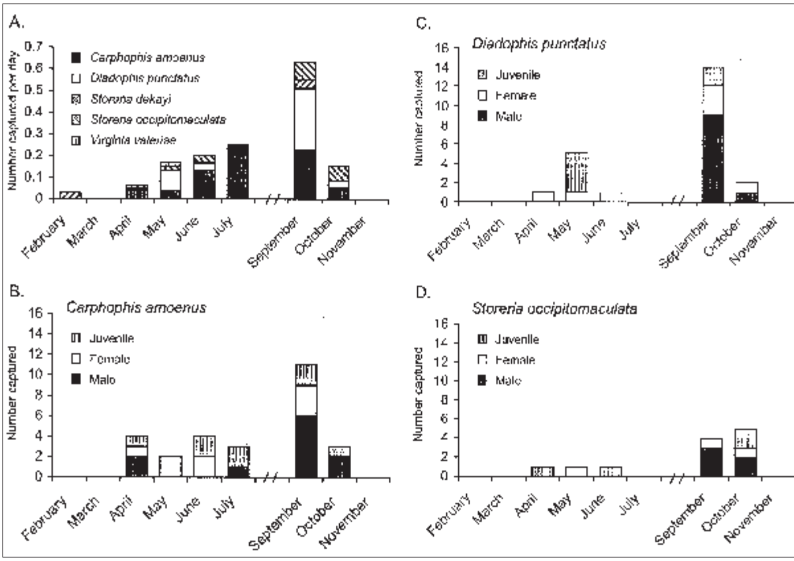

Figure 2. (A) Monthly drift fence capture rates of small fossorial snakes in upland forest around Davidson, NC, between 1999 and 2002. Capture rates were calculated by dividing the number of snakes captured during that month by the total number of days that pitfalls were open in that month. Note that fences were not sampled in August, December, or January, and were sampled only 12 days in July. (B, C, D) Numbers of each sex of the three species of snakes most commonly captured in drift fences during each month between 1999 and 2002.

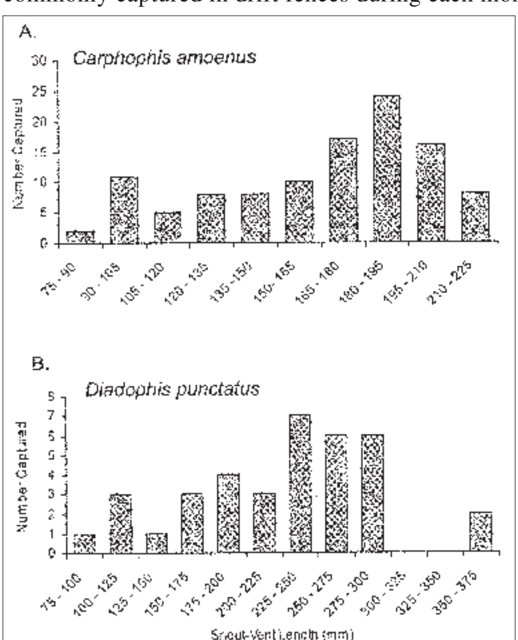

Figure 3. Size frequency distributions for the two most common small snake species captured near Davidson, NC, between 1999 and 2002.

Significant sexual size dimorphism was observed in *C. amoenus*, with females longer (F = 14.01, df = 74, p = < 0.001) and heavier (F = 16.07, df = 64, p = < 0.001) than males (Table 1). Body shape, however, did not differ between the sexes (F = < 0.01, df = 84, p = 1.000). Male *C. amoenus* also had significantly longer tails (F = 14.01, df = 73, p = < 0.001) and longer tail lengths as a percentage of their total length (F = 94.90, df = 73, p = < 0.001) than females.

Female *D. punctatus* were longer (F = 6.81, df = 23, p = 0.016) and heavier (F = 5.07, df = 24, p = 0.034) than males but the sexes did not differ in body shape (F = <0.01, df = 30, p = 1.000). Male *D. punctatus* also had longer tail lengths as a percentage of their total length (F = 5.83, df = 22, p = 0.025) than females. Female *S. dekayi* were heavier than males (F = 7.61, df = 11, p = 0.019) and males had longer tail lengths as a percentage of their total length (F = 6.92, df = 12, p = < 0.022). Sexual dimorphism was not detectable in other species, likely due to small sample sizes.

Eight clutches of eggs were palpated in female *C. amoenus*. Clutches (with SVL of females) numbered 3, 3 (231, 232 mm), 4, 4, 4, 4 (230, 246, 260, 260 mm), and 5, 5 (190, 230 mm). One *D. punctatus* (SVL = 287 mm) contained 6 eggs and one *S. occipitomaculata* (SVL = 183 mm) contained 10 ova. Two gravid *V. valeriae* (206 mm and 210 mm SVL) each contained 6 ova.

Other studies have suggested that *C. amoenus* feed predominantly on earthworms (Clark 1970, Hamilton and Pollack 1956, Minton 1972, Uhler et al. 1939). Although our study did not specifically examine diet,

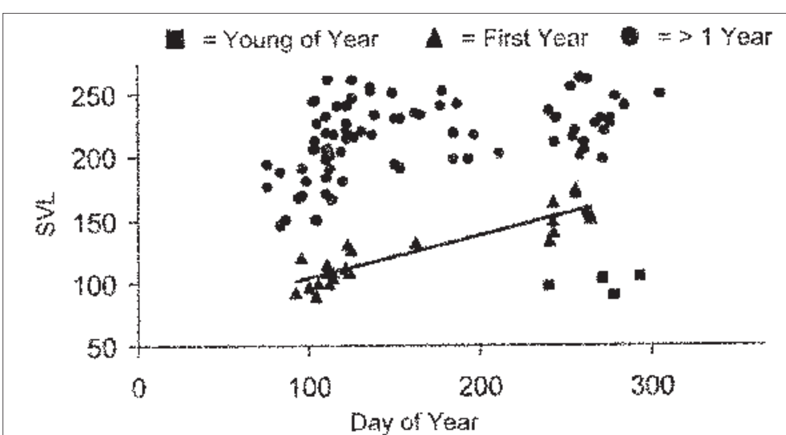

Figure 4. Distribution of snout-vent lengths (mm) of *Carphophis amoenus* in relation to date of capture (cumulative 1999–2002). Symbols represent young-of-year, first year, and mature age classes. Best-fit line for first year snakes approximates what we suspect to be growth pattern of juveniles during their first year (equation: $y = 0.34x + 70.66$).

three *C. amoenus* regurgitated earthworms upon capture, supporting the supposition by Brown (1979, 1992) that *C. amoenus* in our area are also primarily worm eaters. One *D. punctatus* regurgitated an adult ground skink (*Scincella lateralis*) confirming that eastern *D. punctatus* consume some reptiles in addition to earthworms and salamanders.

DISCUSSION

Carphophis amoenus were the most commonly captured small fossorial snake during this study, and were captured more frequently relative to *D. punctatus* in dry upland forest than damp lowland forest. This species was also commonly captured under artificial cover objects in old fields and power line right-of-ways. We observed pronounced female-biased sexual size dimorphism in *C. amoenus*, as is generally the case in small snakes and is often associated with increased fecundity of females (Shine 1984, 1993). Females were longer and heavier than males, but males had longer actual and relative tail lengths. *Carphophis amoenus* in this region appear to be slightly larger than those found in Virginia (Mitchell 1994) and in the Coastal Plain of South Carolina (Russell and Hanlin 1999).

Although the summer months were undersampled, drift fence captures suggest that *C. amoenus* activity in this region peaks in September and does not correlate strongly with rainfall or maximum air temperature. A similar peak in activity was noted in October around isolated wetlands in the Lower Coastal Plain of South Carolina (Russell and Hanlin 1999). Russell and Hanlin (1999) theorized that this activity peak reflected increased movement by males during a fall breeding season, resulting in increased captures in drift fence pitfalls (Parker and Plummer 1987, Semlitsch et al. 1981). Our captures in September were strongly male biased and thus support this hypothesis. These findings are also similar to those of Clark (1970) who described a primary fall mating season for *C. vermis* in Kansas with a less pronounced mating period in the spring.

We captured gravid *C. amoenus* between 21 April and 3 June, with clutch sizes ranging from 3–5 eggs. Although we found few hatchlings, our data support conclusions by Palmer and Braswell (1995) and Brown (1992) that egg laying in North Carolina occurs in early summer and hatching in August and September. Growth patterns of juvenile *C. amoenus* became apparent when SVL was examined in relation to capture date (Fig. 3). Young *C. amoenus* apparently emerged from their first hibernation in late March near 95 mm SVL and reached sexual maturity (170 mm; Palmer and Braswell 1995, Russell and Hanlin 1999) at about one year of age. We could not distinguish age classes older than one year.

Brown (1992) noted that *D. punctatus* were rare in the western Piedmont of North Carolina, and much more common in the Coastal

Plain and Mountains. In contrast, we found *D. punctatus* common, likely due to our use of a more complete repertoire of sampling techniques (Gibbons et al. 1997, Rice et al. 2001). In particular, we found *D. punctatus* to be most susceptible to capture by drift fence. A possible explanation for this trend is that *D. punctatus* has an unusually large home range for its size, averaging 6476 m^2 in Kansas (Fitch 1975), compared to 253 m^2 for *C. amoenus* in Kentucky (Barbour et al. 1969). In addition, *D. punctatus* were captured more frequently in damp lowland forest than in dryer upland forest.

Diadophis punctatus in our region apparently represent intergrades between the northern (*D. p. edwardsii*) and southern (*D. p. punctatus*) subspecies (Palmer and Braswell 1995), with most specimens exhibiting a continuous neck ring and a boldly spotted venter. Like other studies in North Carolina (Palmer and Braswell 1995), we found *D. punctatus* to be sexually dimorphic in length (SVL), mass, and relative tail lengths. However, no sexual dimorphism in body shape was observed in this species.

Previous studies have suggested that eastern *D. punctatus* mate in the spring, however few copulating pairs have been observed (15 September, Palmer and Braswell 1995; 16 September, Mitchell 1994). In our drift fence sampling, we found a marked activity peak in September that was not strongly correlated with climatic variables. Similar to *C. amoenus*, captures during this season were strongly male biased, suggesting that *D. punctatus* in our region breed during the fall. Examination of gonadal development and cloacal smears would help to clarify the breeding season for this species in our area.

The third and fourth most abundant snakes in this study were *S. dekayi* and *S. occipitomaculata* with 24 and 20 captures, respectively. As noted in other studies (Hulse et al. 2001, Mitchell 1994, Neill 1950, Palmer and Braswell 1995), *S. dekayi* were most frequently encountered in suburban neighborhoods and other developed areas. *Storeria occipitomaculata* were captured more frequently than *S. dekayi* in our drift fences in undeveloped habitats.

Other studies report sexual dimorphism in both *S. dekayi* and *S. occipitomaculata*, with females of both species longer (SVL), heavier, and with shorter relative tail length than males (Blanchard 1937, King 1997, Rossman and Erwin 1980, Semlitsch and Moran 1984, and others). Although our sample sizes for these species are small, our data indicate similar trends in sexual dimorphism. As with *C. amoenus* and *D. punctatus*, the majority of our drift fence captures of *S. occipitomaculata* were male snakes captured in September and October, possibly suggesting a fall breeding season.

Although snakes can be important components of many ecosystems, they are often difficult to sample and thus are understudied in comparison to other taxa (Parker and Plummer 1987). Small snakes, in particular, have seldom been specifically studied and in many cases even basic life-history characteristics of common species are poorly understood. While we have begun to better understand the ecology of several species of small fossorial snakes in our region, additional studies are needed to fully understand their natural history and roles they play in various ecosystems.

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