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Reprinted from JOURNAL OF HERPETOLOGY
Vol. 33, No. 2, June 1999

*Journal of Herpetology*, Vol. 33, No. 2, pp. 339–344, 1999


# Aspects of the Ecology of Worm Snakes (*Carphophis amoenus*) Associated with Small Isolated Wetlands in South Carolina

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The worm snake (*Carphophis amoenus*) is a small, secretive, and fossorial species found across much of eastern and midwestern North America (Conant and Collins, 1991). Despite its wide distribution, the few published reports on the ecology of *C. amoenus* are limited to brief life history observations (e.g., Wright and Wright, 1957; Fitch, 1958; Barbour et al., 1969) and distributional accounts (Barbour, 1950, 1960; Mount, 1972; Sajdak, 1978). The only detailed studies concerning the biology of this species were those of Clark (1970) and Aldridge and Metter (1973), whose data concerned the western worm snake (*C. a. vermis*), considered by some authors to be a distinct species (Clark, 1968; Conant and Collins, 1991; but see Rossman, 1973).

The distribution of *C. amoenus* across much of the southeastern Atlantic Coastal Plain is poorly resolved. In other regions of the Southeast, this species is associated with mesophytic upland forests and typically is found under cover objects (e.g., rocks, decaying logs, leaf litter) on the soil surface or buried in loose, moist soil (Mount, 1975; Martof et al., 1980; Mitchell, 1994). However, *C. amoenus* apparently is scarce or absent from much of the Coastal Plain where upland habitats are more xeric and dominated by pines (Clark, 1970; Mount, 1972). In the Coastal Plain of South Carolina, over 25 yr of intensive sampling in a variety of habitats on the 780 km² Savannah River Site have yielded fewer than 25 individuals of *C. amoenus* (Bowers, 1997; Gibbons et al., 1997).

Isolated wetlands are the primary natural lentic habitats on the southeastern Coastal Plain and provide

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critical habitats for several species of aquatic and semi-aquatic snakes (e.g., Semlitsch et al., 1988; Gibbons and Semlitsch, 1991; Dodd, 1993). The peripheries of these wetlands also provide important refugia for species of terrestrial snakes that prefer moist but unsaturated soils (Semlitsch and Moran, 1984; Gibbons and Semlitsch, 1991). Here, we present data on the abundance, movements, sex ratio, body size, and seasonal activity of eastern worm snakes (*C. amoenus amoenus*; hereafter referred to as *C. amoenus*) captured from small isolated wetlands and adjacent upland forests in South Carolina. We document a potential association between *C. amoenus* and the peripheries of isolated wetlands in the southeastern Coastal Plain and suggest that this species may be more common in the region than previous records indicate.

The study area is an 8100-ha tract of managed forest known as the Woodbury Tract, located at the confluence of the Little and Great Pee Dee Rivers in the Lower Atlantic Coastal Plain of South Carolina. The portion of the tract between the two hardwood swamp floodplains consists of moderately- to well-drained upland sandhills dominated by plantations of loblolly pine (*Pinus taeda*) and longleaf pine (*P. palustris*). Interspersed among these sandhills are several large Carolina bays and numerous smaller, non-alluvial isolated wetlands. We selected five small isolated wetlands within the sandhill forest, ranging in size from 0.38 ha to 1.06 ha, as sampling sites. Hydrology at these sites is dependent on seasonal rainfall and groundwater recharge; water depths range from completely dry in summer to ≥0.6 m in winter and early spring. Wetland vegetation at the five sites is similar, with an overstory of baldcypress (*Taxodium distichum*) and pond pine (*P. serotina*), and a dense mesophytic hardwood midstory. The uplands surrounding each wetland are dominated by 18–25 yr-old loblolly pine stands with several oak species (e.g., *Quercus falcata*, *Q. laevis*, *Q. stellata*) in the midstory. Ground cover includes a dense layer of pine straw and several herbaceous species, with the exception of the ecotone between the wetland and upland habitats which is dominated by an understory of fetterbush (*Lyonia* spp.). Distances between the five wetlands range from 402 m to 1509 m.

We completely encircled each wetland (designated 1–5) with a continuous drift fence (Gibbons and Semlitsch, 1981) constructed of 60-cm high aluminum flashing or silt fencing, of which 10–15 cm was buried in the ground (192 m, 226 m, 302 m, 366 m, and 271 m in circumference, respectively). Paired pitfall traps (19-L gray plastic buckets) were buried on each side of the fences at 10-m intervals. We positioned drift fences just above the anticipated high-water mark; in the ecotone between the periphery of the wetland depression and the upland pine stands. To sample the adjacent uplands, we arranged individually numbered plywood coverboards (0.61 m × 1.22 m; Grant et al., 1992) in linear arrays of 20 boards each, with three arrays equally spaced around each wetland. We placed the first board in each array at the wetland periphery and subsequent boards extended into the upland stand at 10-m intervals. Thus, the most distal board in each array was 190 m from the wetland.

We checked pitfall traps and coverboards daily from 19 September 1996 to 19 January 1998 (wetlands 1–3) or 22 April 1997 to 19 January 1998 (wetlands 4 and 5). We returned captures to a field station at the study area, where we measured snout–vent length (SVL) and total length (TL) to the nearest mm with a plastic ruler and mass to the nearest 0.1 g with an electronic balance. Because captured *C. amoenus* were part of a larger, ongoing study they could not be sacrificed to determine reproductive status (i.e., maturity). However, hatchlings were easily differentiated from other age-classes by their small size and darker, sharply demarcated dorsal and ventral coloration (Clark, 1970; Ernst and Barbour, 1989). All individuals ≥170 mm SVL were considered mature (Clark, 1970); individuals below this body size, excluding hatchlings, were considered juveniles. Adult snakes were sexed by probing for the presence of hemipenes. We marked snakes with SVL ≥ 150 mm by inserting 14-mm passive integrated transponders (PIT tags) intra-abdominally in the posterior ⅓ of the body (Camper and Dixon, 1988). This minimum size was chosen because it was difficult to insert tags into smaller snakes without causing injury and initial tagging efforts prior to the study resulted in the death of two small snakes. No juveniles or hatchlings were marked. Snakes were treated with anti-bacterial ointment at the point of tag insertion and held 12–24 h for observation before release at the point of capture (on the opposite side of the drift fence or replaced under the coverboard).

We recorded daily precipitation, air temperatures (maximum, minimum), and maximum water depth at each of the five wetlands. Stepwise regression was used to evaluate the relationship between abundance and environmental factors, with the number of captures per month (pooled from all sites) regressed against monthly mean maximum and minimum air temperatures, mean temperature range (maximum minus minimum), cumulative monthly rainfall, and mean water depth. We used JMP 3.1 (SAS Inst. Inc., 1995) for all analyses with the level of significance set at $\alpha = 0.05$ and means reported ±1 standard deviation (SD) unless otherwise noted.

A total of 129 *Carphophis amoenus* was captured from the five wetlands and adjacent upland stands. We collected most snakes at drift fences in the wetland periphery (71 inside fence, 44 outside); upland coverboard arrays accounted for only 11% (14/129) of captures. For coverboard captures, distance between the point of capture and wetland periphery averaged 114.6 ± 53.0 m (median = 115 m, range = 30–190 m). Of 92 snakes marked with PIT tags, only eight (9%) were recaptured. Only one coverboard capture was recaptured, from under the same board after 14 d; the other seven represent individuals collected and recaptured at the drift fences. Sixty-three percent (⅝) of recaptures occurred within 30 m of the original capture site ($\bar{x}$ = 63.8 ± 66.9 m, median = 30 m, range = 0–180 m), and the interval between release and recapture averaged 72.6 ± 80.3 d (median = 49.5 d, range = 3–238 d). There was no correlation between capture-recapture interval and distance of movements ($r^2$ = 0.07, df = 7, $P$ = 0.52). We also did not record any movements of marked *C. amoenus* among wetlands or coverboard arrays. The limited number of recaptures did not warrant calculation of population size using a mark-recapture index. Instead, to compare relative abundance among wetlands (Semlitsch et al., 1981),

TABLE 1. Standardized relative abundance (all captures) of *Carphophis amoenus* collected by drift fences at the periphery of five isolated wetlands in the Coastal Plain of South Carolina, April 1997 to January 1998.

| Wetland | Area (ha) | Total linear distance of drift fence (m) | Number of Captures | Captures/100 m of drift fence |
|---|---|---|---|---|
| 1 | 0.38 | 192 | 19 | 9.9 |
| 2 | 0.47 | 226 | 9 | 3.9 |
| 3 | 0.72 | 302 | 18 | 5.9 |
| 4 | 1.06 | 366 | 22 | 6.0 |
| 5 | 0.59 | 271 | 14 | 5.2 |
| Mean ± 1 SD | | | 16.4 ± 5.0 | 6.2 ± 2.2 |

TABLE 2. Body sizes of adult, juvenile, and hatchling *Carphophis amoenus* from the Coastal Plain of South Carolina, September 1996 to January 1998. Values are means ± 1 SD. Ranges are in parentheses.

| | N | Body mass (g) | Snout–vent length (mm) | Tail length (mm) |
|---|---|---|---|---|
| Adult | | | | |
| Female | 34 | 5.0 ± 1.5 (2.6–8.5) | 218.6 ± 27.3 (170–285) | 26.8 ± 7.6 (10–40) |
| Male | 64 | 4.4 ± 1.2 (2.0–8.0) | 206.8 ± 19.0 (170–290) | 44.9 ± 8.3 (31–85) |
| Juvenile | 23 | 2.4 ± 0.6 (1.7–4.1) | 146.1 ± 14.6 (125–167) | 32.3 ± 19.1 (15–70.1) |
| Hatchling | 8 | 0.8 ± 0.2 (0.6–1.2) | 98.3 ± 11.1 (80–115) | 18.9 ± 6.6 (10–26) |

the total number of captures (including recaptures) from the 215 overlapping drift fence array-nights (22 April 1997 to 19 January 1997) was standardized to the number of captures per 100 m of drift fencing for each wetland (Table 1).

For adult *C. amoenus*, the sex ratio was significantly different from 1:1 (64 males/34 females; $\chi^2 = 9.18$, df = 1, $P < 0.01$). Adult *C. amoenus* were sexually dimorphic in body size (Table 2). Females were larger in mean SVL (unpaired $t = 2.38$, df = 96, $P = 0.019$) and mean mass (unpaired $t = 2.07$, df = 96, $P = 0.041$) than males, while mean tail length of males exceeded that of females (unpaired $t = -10.77$, df = 96, $P < 0.0001$). Juveniles and hatchlings comprised only 18% and 6% of captures, respectively (Table 2).

Adult *C. amoenus* were collected in all months of the study except February, juveniles were encountered from May through November, and hatchlings were captured only during two disjunct periods in the spring and fall (Fig. 1). Peak activity occurred in October and November. The stepwise regression indicated that only maximum air temperature explained a significant portion of the variation in number of captures ($r^2 = 0.24$, $F = 4.65$, $P < 0.05$).

Although the large proportion of *C. amoenus* captured in the ecotone between wetland and upland habitats is in part related to differences in the sampling effectiveness of drift fences and coverboards

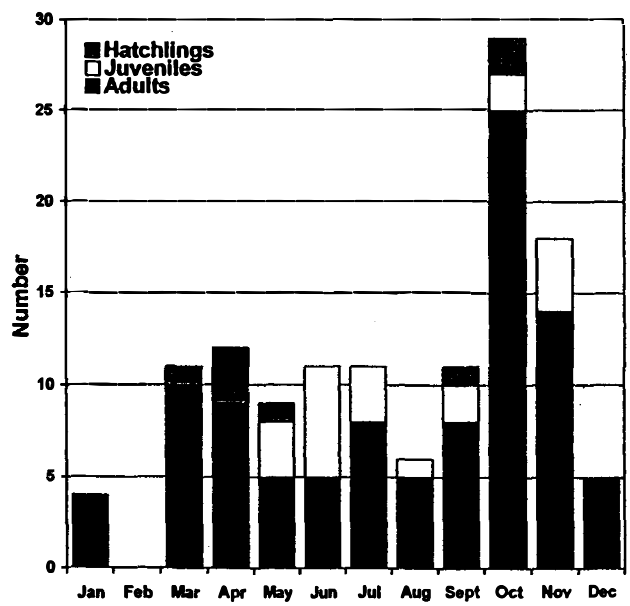


FIG. 1. Monthly occurrence of hatchling, juvenile, and adult *Carphophis amoenus* from the periphery of small isolated wetlands and adjacent upland sandhills in the Coastal Plain of South Carolina, September 1996 to January 1998.

(Grant et al., 1992), this species rarely is captured by drift fences in nearby upland stands without isolated wetlands (J. W. Gibbons, pers. comm.). We believe that the aggregation of C. *amoenus* in the narrow zone between aquatic and upland environments likely reflects the presence of preferred microhabitats (e.g., cool and moist but unsaturated soil, leaf litter; Clark, 1970) and abundant prey (e.g., earthworms; Barbour, 1960; KRR, pers. observ.). Differences in the relative abundance of snakes were not related to wetland size (Table 1), and probably indicate local variation in microhabitat and environmental conditions such as soil moisture (Clark, 1967, 1970; Ernst and Barbour, 1989) or differences in wetland hydrology (Semlitsch and Moran, 1984).

The low number of recaptures indicates that C. *amoenus* is abundant in the periphery of isolated wetlands or that there is rapid turnover of individuals in the population. Low rates of recapture appear characteristic of mark-recapture studies with C. *amoenus* (7%; Fitch, 1958; 15%; Clark, 1970) and snakes in general (Parker and Plummer, 1987). The high densities of C. *amoenus* reported from Kansas (60–120 individuals/ha; Clark, 1970) and Kentucky (108 individuals/100-m transect/1 h; Ernst and Barbour, 1989) indicate that this species is very abundant in areas of suitable habitat. Alternatively, low rates of recapture may reflect low adult survivorship but high juvenile recruitment or high rates of immigration and emigration (Semlitsch and Moran, 1984; Parker and Plummer, 1987). In our study, the relatively high proportion of large individuals of both sexes within the total capture may indicate low mortality of adults (Clark, 1970). Also, the paucity of captures in nearby upland stands and apparent limited vagility of C. *amoenus* (see below) indicate that rates of immigration and emigration probably are low.

Although the sample size is small, our findings support previous reports that C. *amoenus* exhibits limited movements. In our study the individual with the largest capture-recapture interval (238 d) was recovered only 30 m from the original point of release, and another C. *amoenus* was recaptured under the same coverboard after 14 d. Previously, Fitch (1958) documented only four movements of 19 marked C. *amoenus* over 1.5 m (range = 6–125 m), while Barbour et al. (1969) found that home ranges of 10 C. *amoenus* in Kentucky averaged only 253 m$^2$. Because we did not mark juvenile or hatchling C. *amoenus*, it is possible that we have underestimated movement distances, including movements between wetlands. However, Clark (1970) reported that juveniles of C. *amoenus* are less vagile than adults. Our recaptures at the drift fences indicate that most activity probably is concentrated in the mesic ecotone surrounding the wetlands, and we believe that significant movements of C. *amoenus* into the more xeric uplands, and thus potential formation of metapopulations (Hanski and Gilpin, 1991), may only occur during very wet periods when wetland boundaries expand (Semlitsch and Moran, 1984) and many Coastal Plain isolated wetlands are interconnected (Dodd, 1993; KRR and HGH, pers. observ.).

The age composition of our sample of C. *amoenus* is typical for species of small snakes (Parker and Plummer, 1987). Samples of snake populations often consist of large proportions of adults when compared to hatchlings and juveniles, which may reflect a sampling bias resulting from the higher vagility and activity of adults relative to other age classes. Although the population sex ratio typically is 1:1 for C. *amoenus* and other small snakes, more males often are captured during the breeding season, possibly resulting from their greater activity and movements as they search for females (Clark, 1970; Semlitsch et al., 1981; Parker and Plummer, 1987). In our study, the adult sex ratio was highly male skewed and may reflect a trapping bias from the more active males being caught more frequently in pitfall traps during the breeding season (Clark, 1970; Semlitsch et al., 1981), but alternative explanations include differential survivorship and genetic mechanisms (Clark, 1970; Parker and Plummer, 1987).

Body sizes of adult, juvenile, and hatchling C. *amoenus* in South Carolina are similar to previously reported values from other locales (Clark, 1970; Ernst and Barbour, 1989; Mitchell, 1994). We found that females are larger in SVL and mass than males, while tail length is greater in males than in females. These patterns of sexual dimorphism have been found in other populations of C. *amoenus* (Clark, 1970; Ernst and Barbour, 1989; Mitchell, 1994), and are common in many species of snakes (Shine, 1993).

Our finding that adults of C. *amoenus* were captured most frequently in October and November is consistent with the previous suggestion by Clark (1970) that most mating occurs in the fall (apparently females store sperm over winter), with a lesser copulatory period in the spring. Newly hatched young typically are found in the summer and fall (Clark, 1970; Ernst and Barbour, 1989; Mitchell, 1994), and unhatched eggs have not been found in the winter or spring. Thus, hatchlings that we captured March–May most likely are from clutches deposited the previous year. Captures of C. *amoenus* were positively correlated with air temperature, which previously has been reported for this and other species of small snakes (e.g., Clark, 1970; Semlitsch et al., 1981; Semlitsch and Moran, 1984). However, surface activity of C. *amoenus* is restricted during very hot weather (Clark, 1970; Ernst and Barbour, 1989), as indicated by our low number of captures in August. In the central United States, worm snakes typically are found between April and October (Clark, 1970), but have been observed as late as December in Virginia (Mitchell, 1994). The period of activity observed in our study (March–January) is the longest reported for this species, and probably reflects the mild winter climate in the South Carolina Coastal Plain (Gibbons and Semlitsch, 1991).

Perhaps because of their small size and ephemeral nature, many isolated wetlands continue to be overlooked as important habitats for herpetofauna in Coastal Plain upland ecosystems (Dodd, 1992; Dodd and Cade, 1998). In the last 30 years, 84% of wetland losses in the United States have occurred in the Southeast and many of the smaller isolated wetland communities may be declining at an equal or greater rate (Sutter and Kral, 1994). Although C. *amoenus* does not require wetlands per se, we believe that forested wetland peripheries provide favorable but previously unrecognized "islands" of habitat for this species within the more xeric sandhill forests of the southeastern Coastal Plain. Thus, we also suggest that C. *amoenus* is more common in portions of this region than previous records indicate, although continued wetland losses may increasingly isolate populations that already are patchily distributed. Additional studies are needed to characterize more completely the distribution and ecology of this small, secretive species in the southeastern United States.

*Acknowledgments.*—This research was supported by the U.S. Forest Service, Center for Forested Wetlands Research (Charleston, SC), under Cooperative Agreement 18-409, Supplement 182. The Savannah River Ecology Laboratory and National Council of the Paper Industry for Air and Stream Improvement also provided financial support. Appreciation is extended to International Paper, on whose land this study was conducted. D. Hill and B. Metts aided in the field work; Y. Leiden and W. Smith provided additional logistical support. We thank J. W. Gibbons, F. D. Martin, C. K. Dodd, Jr., S. J. Mullin, and an anonymous reviewer for critical comments that significantly improved this manuscript. All capture and marking protocols were approved by the Clemson University Animal Research Committee (ARC Protocol #97-009).

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Accepted: 23 January 1999.