Microhabitat use by the Eastern worm snake, *Carphophis amoenus*

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ABSTRACT — Soil moisture, soil pH, and temperature of microhabitats used by the Eastern worm snake, *Carphophis amoenus*, were measured at Mason Neck National Wildlife Refuge, Fairfax County, Virginia. Microhabitat soil moisture ranged from 10-83% depending on the season and year. Soil pH had a mean of 6.1. The range (5.0-6.9) was similar to the preferred range of the Eastern worm snake's main prey, the earthworm. Cloacal temperature was moderately correlated to air and substrate temperatures and varied significantly depending on time of day, season, or year. There were no significant differences between males and females or adults and juveniles for any of the parameters. Eastern worm snakes were found at a wide range of soil moistures, soil pHs, and temperatures. Eastern worm snakes, particularly males, showed site fidelity but were also capable of quickly exploiting new habitats.

THE Eastern worm snake, *Carphophis amoenus,* is probably the most common snake in northern Virginia (Ernst *et al.*, 1997). It is seldom noticed or studied, however, because of its small size, cryptic lifestyle, and lack of glamour, relative to other larger or venomous snakes. Little specific habitat data and no growth data exist for this species (Ernst *et al*., 2003). It is most often found under rocks and logs and occurs in a wide variety of habitats (Barbour, 1960). Barbour *et al*. (1969) found that its average home range is relatively small (253 m^2) and that its daily activity peaks between 15:00 and 18:00 hours. Hartsell (1993) studied the thermal ecology of *Carphophis amoenus* at the Mason Neck National Wildlife Refuge and found that air temperature, substrate temperature, activity, and daily high and low environmental temperatures may all help to predict the snake's cloacal temperature. The purpose of this study is to describe microhabitat use by the Eastern worm snake, *Carphophis amoenus*, and compare it to the Western worm snake, *Carphophis vermis*.

METHODS AND MATERIALS

The research was conducted from April 2001 through June 2003 at the Mason Neck National Wildlife Refuge, Fairfax County, Virginia (38°38'14"N,77°11'41"W). Mason Neck is one of several sites in the Washington, D.C. area known to have a large population of *Carphophis amoenus* (C. Ernst, pers. comm.). Creque (2001) estimated the snake's population size at the site to be 100 individuals, with a population density of 9.7/ha. The study site at Mason Neck is closed to the public and so receives minimal disturbance.

Sampling effort was concentrated in the spring months when *Carphophis* was most likely to be encountered (Creque, 2001), ended each fall in November prior to an annual deer hunt on the refuge, and resumed the following spring in late March or April. Coverboards, concrete blocks, large wood ties, sheets of roofing tin, and natural cover were checked periodically for *Carphophis*. Unfortunately, extensive tree roots from secondary growth trees limited digging, so pitfall traps could not be used. Because of their small size, the worm snakes could not be tracked with radio transmitters or tagged with PIT tags, and so captured snakes were marked with a numerical identification code by clipping their ventral scales. Soil moisture and pH of capture sites were determined at the time of capture with a KELWAY® Soil Acidity and Moisture Meter. In some cases, the soil was too thin or rocky and the moisture and pH could not be read and these measurements were not attempted when the snake was found inside a log. During the summer and fall of 2001, soil moisture readings were taken at a fixed location at a depth of 20 cm using a Delmhorst digital soil moisture meter and gypsum blocks. Days that worm snakes were encountered were compared to days that they were not encountered.

Cloacal temperatures, substrate temperatures, and air temperatures were recorded as soon as a snake was found. Cloacal temperatures were taken with a Miller and Webber Schultheis quick-reading cloacal thermometer accurate to 0.2°C. Gloves were worn to minimalize human heat transfer to the snake and the snakes were handled as little as possible while inserting the bulb of the thermometer into the cloaca. It was not possible to take the cloacal temperature of small juveniles, and if the snake required much handling to record its cloacal temperature that datum was discarded. Air and substrate temperatures were also taken at time of capture (including at the site where an individual snake had escaped) using a Hanna Instruments 9053 thermocouple thermometer. Air temperature was recorded at a height of 10 cm above the initial position of the snake. Substrate temperature was measured by inserting the probe under the cover item to the approximate position of the snake.

Snout-vent length and total length were measured by holding the snake along a measuring tape, and the snake's body mass was recorded with a 30 g Pesola spring scale. Cloacal temperature, air temperature, substrate temperature, snake behavior, sex, health, date, time, and location of capture were also recorded.

Data were analyzed using the SAS 8.2 program. Two sample t-tests were used to compare the means. A Mann-Whitney test was conducted to compare medians of fixed location soil moisture (Chase & Bown, 1997). Significance level for all tests was set a priori at < 0.05.

RESULTS

The mean percent of 62 soil moisture measurements was 53% (10–83%, n=62). No significant differences were found between the average soil moistures for males and females or adults and juveniles. Males had a greater range (10%–83%) than both females (35%–80%) and juveniles (29%–75%). Also notable is the difference in soil moisture at capture sites from month to month (Fig. 1) and from year to year. Mean soil moisture at the capture site for 2003 was 63.5% (35–83%), significantly higher (p=0.05) than the mean soil moisture for the corresponding months of 2002, 47.4% (28–60%). There was no statistical difference in the soil moistures at the sites where the *Carphophis* were found undergoing ecdysis. It is interesting to note, however, that all shedding events observed took place during the wet months of May and June, except for one observation in September. The median soil moisture at a fixed location was significantly higher for days that worm snakes were encountered, 91.3% (41.1–96.4%), than for days that they were not encountered, 21.4% (1.3–96.2%).

At Mason Neck, the mean soil pH of 62 capture sites was 6.1 (5.0–6.9). Mean soil pH did not differ significantly among adult males, adult females, or juveniles.

Mean cloacal temperature for the total sample of 110 adults was 22.4 °C (11.0–33.0 °C), that of 62 adult males was 22.1 °C (11.0–33.0 °C), and of 33 adult females was 22.5 °C (12.0–30.8 °C). The difference between sexes was not significant. It was not possible to compare body temperatures of juveniles and adults because of the difficulty in taking juvenile cloacal temperatures due to their small and narrow bodies.

Cloacal temperature was significantly correlated to both air temperature (r = 0.792) and substrate temperature (r = 0.768). Adults were found at a mean air temperature of 20.6°C (10.5–38.7°C) and a mean substrate temperature of 20.2°C (11.0–33.5°C). Juveniles were found at a mean air temperature of 20.8°C (13.5–29.6°C) and a mean substrate temperature of 20.5°C (12.7–32.3°C). Although juveniles made up 14.8% of the total captures for 2001 and 2002, none were found during July and August – the two hottest, driest months at Mason Neck. Most *Carphophis* eggs laid at Mason Neck hatch in late August or September (C. Ernst, pers. comm.)

Mean cloacal temperature for all snakes in 2003 (18.4ºC) was significantly lower than for the corresponding months of 2002 (23.3ºC) and 2001 (24.3ºC). The mean cloacal temperature for 2001 and 2002 combined was 24.0ºC, which was not significantly different from the means calculated in other studies at Mason Neck (Hartsell, 1993; Creque, 2001).

In this study, cloacal temperature rose during the day (Table 1). The differences between those recorded in the early and late morning and the differences between those taken in early morning and the afternoon are significant. The mean for afternoon captures is higher than that of those

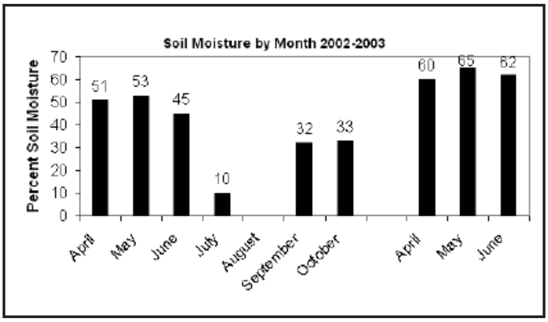

Figure 1. Average soil moisture at capture sites by month at the Mason Neck National Wildlife Refuge (only one *Carphophis amoenus* was captured in August).

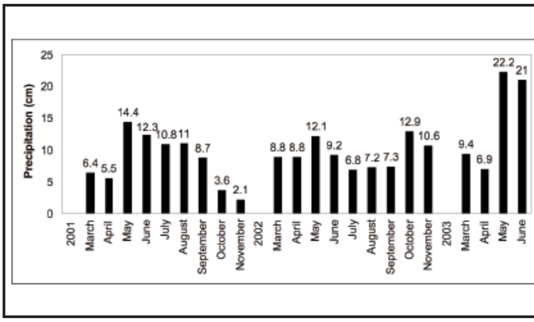

Figure 2. Monthly precipitation in Washington D.C. during months of study (National Climatic Data Center).

from late morning, but this difference was not significant.

All recaptures were under the same cover object or nearby. Of 68 captures of adult males, 30 (44%) were recaptures. Of 36 captures of adult females, only 4 (11%) were recaptures. Most recaptures occurred within a few days of the original capture, and it was not clear if the individual snake had moved during the intervening time period. At other times, the snake was not present when the specific cover item was checked, but later returned to the same location.

DISCUSSION

Soil Water Content — Mean soil moisture of microhabitats was significantly higher ($p<0.01$) than like means reported for Kansas *Carphophis vermis* (Table 2). Clark (1970) found Kansas *Carphophis vermis* at soil moistures from 17.6–73.5%, but they were found most often at soil moisture levels of 21-30%. Soil moisture of *C. vermis* averaged 33.8% for males and 31.5% for females, but this difference was not significant. Small *C. vermis* (less than 200 mm) had a higher average (37.8%) than large individuals (30.9%), but again the difference was not significant. Elick and Sealander (1972) found 20 Kansas *C. vermis* within a soil moisture range of 15.9-42.1% (mean 20.4%). In the laboratory, *Carphophis vermis* were given a choice of 14-30% soil moistures and averaged 25% (Clark, 1967), significantly lower than the mean for this study.

The last year of the Mason Neck study, 2003, was an unusually wet and overcast year, while 2001 and 2002 were dry years (Figs. 2 and 3); however, such short term field studies are unlikely to detect the year-to-year variations that organisms must be able to tolerate.

Many snakes in the laboratory select different habitats with the onset of ecdysis, but this has not been well documented in free-ranging snakes (Reinert, 1993). Under natural conditions, the cost of this behavior may outweigh the benefits. Moving to a more optimal environment results in a cost of energy and greater exposure to predators at a time when the snake's vision may be occluded.

Limitations exist in taking soil moisture at a fixed location. Soil moisture at a single location does not adequately represent the complete range and variation of soil moistures available in different microhabitats. Despite these limitations, the similarity in maximum values at Mason Neck indicates that soil moisture alone does not signify the presence of worm snakes, but may play a role in their microhabitat selection. The difference in medians and minimums, however, suggests that at low soil moisture levels worm snakes move to more moist sites inside logs, deeper into the soil,

Table 1. Time of day and mean cloacal temperature of *Carphophis amoenus* at the Mason Neck National Wildlife Refuge.

Time of Day	Time	Mean	*n*
Early morning	Before 09:30	19.8	37
Late morning	09:30 to 12:00	23.2	32
Afternoon	After 12:00	25.2	20

Study	Species	Mean %	Range %
This Study	*C. amoenus*	53	10–83
Elick & Sealander (1972)	*C. vermis*	20.4	15.9–42.1
Clark (1970)	*C. vermis*	–	17.6–73.5
Clark (1967)	*C. vermis*	25	–

Table 2. Summary of soil moisture preferences of species of *Carphophis* from different studies.

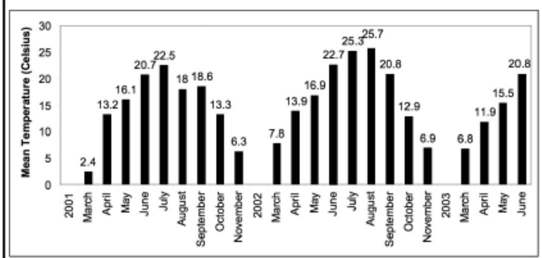

Figure 3. Monthly mean temperature in Washington D.C. during months of study (National Climatic Data Center).

or to other microhabitats where they are less easily sampled. Johnson *et al*. (2004) reported that activity level of *C. vermis* was unaffected by rainfall within 24 h of sampling.

Soil pH — The distribution of *Carphophis amoenus* is probably influenced by soil pH. Sugalski and Claussen (1997) found that soil pH was the most influential factor influencing distribution of the salamander, *Plethodon cinereus*, and Wyman (1988) reported that the distribution of five species of amphibians was significantly influenced by soil pH. Of 16 species of amphibians studied, 11 may have been selecting areas of high soil pH or avoiding areas of low soil pH. *Carphophis amoenus* may not be found in acidic soils for the same reasons that amphibians avoid them. Low pH on the soil surface may indicate different conditions at deeper levels, such as in hibernacula, and may cause the build up of heavy metals or the decrease of essential ions (Wyman, 1988). Low pH has been shown to depress sodium uptake and increase sodium loss in amphibians (Frisbie & Wyman, 1992), and may possibly affect small snakes in the same way. Soil pH is also important in determining the composition of the plant community which determines which other organisms are present. Animals may simply avoid low pH if they are able to sense it, as low soil pH may reduce the availability of prey (Wyman, 1988). Earthworms, the main prey of *Carphophis amoenus* (Ernst & Ernst, 2003), may vary in soil pH preference by species but are most numerous in soils with pH 4.5–7 and are absent from soils where pH < 3.5 (Lee, 1985). The range of soil pH observed for Eastern worm snakes at Mason Neck matches the preferred range of earthworms. Unfortunately, this tells us nothing of the limits of pH tolerance of the snake.

Temperature — Although juveniles might be expected to occur at lower temperatures because they are more susceptible to dessication, the difference between mean substrate temperature and air temperature for adults and juveniles was not significant. Two earlier studies found higher mean cloacal temperatures for *Carphophis amoenus* at Mason Neck than occurred during the present study (Table 3). Creque (2001) reported a significantly higher mean cloacal temperature of 23.9°C for 161 *C. amoenus* during the years 1997–2000, and Hartsell (1993) found that 60 *Carphophis amoenus* at Mason Neck had a significantly higher mean of 24.58°C (16–32°C) during 1991–1993. In her study, 23 males averaged 24.89ºC (19.0–30.0ºC), 27 females averaged 24.47ºC (16.0–30.5ºC). The difference in means between these studies could be attributed to differences in collecting season, differences in collecting times, or annual climatic variation.

The time of day that field work was performed probably has an effect on mean temperature. By late morning and early afternoon the snake had probably reached its optimal temperature. This is consistent with Barbour *et al*. (1969) who found that most movement by *C. amoenus* occurred in the afternoon. However, Johnson *et al*. (2004) reported that *C. vermis* activity level was not affected by temperature.

In a laboratory study, Clark (1967) found that 31 Kansas *C. vermis* preferred a body temperature of

Study	**Species**	**Mean (°C)**	**Range (°C)**	***n***
This study*	*C. amoenus*	22.1	11.0–33.0	110
Creque (2001)*	*C. amoenus*	23.9	10.0–32.2	161
Hartsell (1993)*	*C. amoenus*	24.58	16–32 60	
Fitch (1999)	*C. vermis*	25.7	19–31.7	21
Clark (1970)	*C. vermis*	18.3	9.9–23.8	42
Clark (1967)	*C. vermis*	23.01	14.4–30.8	31

Table 3. Cloacal Temperatures of species of *Carphophis* from Different Studies. * = Mason Neck National Wildlife Refuge.

23.01 °C on a thermal gradient, however, the relationship of laboratory studies to field results is unclear. Snakes in the field may not have their optimal temperature available to them. They may face a trade-off between staying at a less-than-optimal body temperature and expending energy or exposing themselves to predators while trying to find a better microhabitat. Clark (1967) found that the temperatures chosen by Western worm snakes along the thermal gradient ranged from 14.4–30.8°C, indicating that *C. vermis* can tolerate a wide range of temperatures. This is important because small snakes, such as the species of *Carphophis*, are generally less able to control their body temperatures physiologically than are large snakes (Peterson *et al*., 1993). Another reason that individuals of *Carphophis* would be expected to have a wide body temperature range is that a narrow range is incompatible with a snake that spends most of its time underground or under cover, and whose temperature depends largely on the surrounding soil (Clark, 1970). Elick *et al*. (1980) and Clark (1967) thought that lower body temperatures in small snakes are correlated with a greater burrowing tendency. *C. vermis* seems more fossorially adapted than *C. amoenus* because it is larger, more brightly colored, and has a narrower head, shorter tail, and smaller eyes (Fitch, 1999); therefore *C. vermis* should prefer a lower mean cloacal temperature than *C. amoenus*, but it does not seem to do so (Table 1). Fitch (1999) reported that the average body temperature of 21 Kansas *C. vermis* averaged 25.7°C (19–31.7°C), and Clark (1970) found that 42 had a mean body temperature of 18.3°C (9.9–23.8°C) with males having a slightly lower average temperature than females, but the difference was not significant. However, Clark (1970) conducted his study earlier in the day than Fitch (1999), which may explain why Fitch's mean body temperature was higher.

No single body temperature is optimal for all individuals or at all times. The optimal body temperature may depend on other factors such as the degree of hydration of the snake, the time since its last meal, general health, the presence of parasites, and its reproductive condition. Other environmental factors such as soil moisture may also play a role. Seasonal changes in temperature appear to be more important to worm snakes than short-term fluctuations (Clark, 1970). The differences between mean cloacal temperatures for consecutive months at Mason Neck were significant from April to May and from May to June (Table 4).

When *C. amoenus* were found at Mason Neck, they typically were coiled under a cover object. In some cases, when the cover object was removed the worm snake also moved, but more typically, it remained motionless for a few seconds as if it was either startled or possibly unaware that it had been exposed. The coiled body posture is used by cold animals to minimize the body surface that is exposed to colder elements. It also minimalizes regional heterothermy, variation in temperature among different parts of the body. Most of the individuals found during the course of this study were probably thermoregulating to raise their body temperatures. Unfortunately, because the snake is secretive, individuals engaged in other activities were not available for sampling. Hartsell (1993) reported the cloacal temperatures of two exposed individuals were 27°C and 30°C, respectively; few exposed individuals were found during this study. One active individual captured while mating had a cloacal temperature of 24.6°C. These temperatures are higher than the average cloacal temperatures for their respective studies, indicating that active worm snakes may achieve higher body temperatures. There is no evidence as to what is the most common body temperature, particularly when the small snakes are underground.

It is possible that worm snakes aggregate to help control their body temperature. Barbour (1950) found a 'ball' of seven Kentucky *C. amoenus* about 20 cm underground in August, and such aggregations may be related to rare but important habitat (Reinert, 1993). On four occasions during the course of this study two worm snakes were found using the same cover item. On 6th June 2001 a male and female were found under the same rock. They were coiled next to each other, their bodies touching slightly. On 17th May 2002 a male and female were discovered under the same coverboard but several centimeters apart. On 14th June 2003 two females were found using the same coverboard. One was gravid, and both were about to shed. This indicates that there may be at least some degree of overlap in microhabitat use for gravid and nongravid females. Finally, on 28th June 2003 a male and female were found mating under a rock.

Month	**Mean (°C)**	**Range (°C)**	***n***
March	23.3	–	1
April	23.3	11.0 – 31.8 27	
May	18.4	12.0 – 26.0 36	
June	26.1	22.4 – 32.4 31	
July	26.4	22.6 – 33.0 7	
August	27.8	–	1
September	25.1	21.6 – 28.6 3	
October	21.1	14.8 – 29.6 5	

Table 4. Monthly Averages of cloacal temperature of *Carphophis amoenus* at the Mason Neck National Wildlife Refuge.

Use of Cover — An abandoned farm at Mason Neck may have been a better habitat for *Carphophis* than the surrounding natural habitat because of the many cover items available there. Artificial shelters, such as a woodpile, were often present in higher densities than natural shelters, which may have made them more attractive to the snakes. The artificial shelters were also usually located in the forest edge ecotonal habitat. It is possible, however, that the *C. amoenus* were simply more accessible to sampling when artificial shelters were used. They are difficult to find when inside logs, deep in the ground, or under the surface leaf litter.

Movements — Several individuals at Mason Neck exhibited site fidelity. This was more common among males than among females. Barbour *et al*. (1969) noted that *C. amoenus* traveled over a limited area and returned periodically to certain cover items or favorable microhabitats.

The most recaptured *C. amoenus* in the present study, #126 (male), serves as an example. It was originally captured 12th June 2001 under a board in a woodpile. It was not seen again until 18th April 2002 when it was recaptured under a coverboard less than 2 m away from the first capture site. It was recaptured under the same coverboard on 20th May, 21st May, 23rd May, 1st June, and 18th June, but on 20th June, it was found under a coverboard adjacent to its usual location. On 29th June and again on 5th Oct 2002, it was under the usual coverboard. On 12th April 2003 it was captured for the last time, at its original location in the woodpile, 669 days after the original capture. This seems to indicate a small home range, but there were many occasions during this period that #126 was not located and it could have gone underground, into logs, under the leaf litter, or moved to a more distant location. The lack of distant recapture sites hampers a conclusive estimation of home range size. Barbour *et al.* (1969) reported that the home range of *C. amoenus* in Kentucky averaged 253 m^2.

Although worm snakes were frequently recaptured under the same cover items, they were also capable of exploiting new habitat. On one occasion, a coverboard which had produced no captures was relocated to a more promising position. The following week a worm snake was found beneath it. On another occasion, an old wooden structure that had housed weather monitoring equipment fell apart. The boards were spread around as cover sites, and were soon utilized by *Carphophis* and other small snake species (*Diadophis punctatus, Thamnophis sirtalis, Storeria dekayi, Virginia valeriae*). These boards became some of the most productive cover sites in the study. The ability to find and make use of new shelters is important to a woodland species that relies on fallen trees for natural cover. The frequent strong storms in northern Virginia bring down many trees, thus drastically altering the landscape from the worm snake's perspective by providing additional cover sites.

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