

# VIRGINIA VALERIAE AND STORERIA DEKAYI IN A NORTHEAST KANSAS GRASSLAND COMMUNITY: ECOLOGY AND CONSERVATION IMPLICATIONS

GEORGE R. PISANI  
Kansas Biological Survey  
2101 Constant Avenue  
Lawrence, Kansas 66047  
gpisani@ku.edu

**Abstract:** Fitch (1999) summarized his fifty years of intensive field work on the snake fauna of the Fitch Natural History Reservation (FNHR) and adjacent study areas, commenting upon the relative scarcity of two small, secretive species, the Smooth Earth Snake (*Virginia valeriae*) and the Brown Snake (*Storeria dekayi*). Location of a population of *V. valeriae* (Pisani 2005) as a component of a diverse snake fauna that includes *S. dekayi* on land adjacent to Fitch's main study areas provided opportunity to accumulate considerable new information on these species in a similar snake community. An intensive mark-recapture study of this community was done from September 2006 through November 2008 and is ongoing. Observations on feeding, defense, home range, morphology, and population size are presented along with relevant microhabitat characteristics. Data accumulated indicate considerably greater use of available grassland habitat by these and syntopic small snake species than has previously been recognized. An extensive review of literature and unpublished dissertations provided insight to aspects of the community interrelations of small vermivorous snakes in northeast Kansas. These interrelations are considered in light of land-management and other anthropogenic factors affecting abundance of earthworms. Conservation implications of these findings are presented, as are suggestions for further study.

## INTRODUCTION

Fitch (1999) summarized his fifty years of intensive field work on the snake fauna of the Fitch Natural History Reservation (FNHR) and adjacent study areas, commenting upon the relative scarcity of two small, secretive species, the Smooth Earth Snake (*Virginia valeriae*) and Brown Snake (*Storeria dekayi*). Location of a population of *V. valeriae* (Pisani 2005) as a component of a diverse snake fauna that includes *S. dekayi* on land adjacent to Fitch's main study areas provided opportunity to accumulate considerable new information on these species in a community similar to that studied by, and thus building upon, Fitch (1999).

Of *Storeria dekayi*, Fitch (1999: 112) noted "less than five records per year, on the average [total = 172 marked in 50 years with but three recaptures]"; Fitch's *Virginia valeriae* records totaled just three over the same 50-year period; the species is recognized as Threatened by Kansas Department of Wildlife and Parks. My 3-year study has yielded 124 *S. dekayi* records (32 recaptures) and 94 *V. valeriae* records (46 recaptures) from one site near the extreme western edge of the range of *V. valeriae*.

Much of the ecological data involving these two species, especially *V. valeriae*, is found in unpublished theses or in published sources that may easily be overlooked. My secondary goal in this paper is to call attention to them by appropriately citing these sources.

## BACKGROUND

Various authors (cf., Todd et al. 2008; Bradford 1973) have noted the difficulty of studying the ecology of *Virginia valeriae* due to its small size (too small for radiotelemetry), secretive nature, and (in at least some parts of the range) patchy distribution. Much prior work involving small, secretive colubrids and natricids refers to their preferred seasonal habitat as some variation of "on wooded slopes under rocks" (cf., Fitch 1956, Clark 1970, Collins 1993), habitats in which collecting such species is reasonably simple. Over time, such description has come to reflect the collecting habits of herpetologists as much as true seasonal habitat prefer-

ences of the snakes. Most previous studies of *V. valeriae* and *S. dekayi* ecology have been conducted by classical "rock turning" methods, including the detailed study (Cervone 1983) of *V. valeriae pulchra* endemic to the Allegheny Plateau of Pennsylvania and New York, and regarded by systematists as derived from *V. v. elegans*, the race found in Kansas. Cervone (1983) found *V. v. pulchra* "in all cases within 15 m from the forest edge" and concluded that the primary habitat is grassy, rock-strewn slopes. Of Cervone's 516 captures, 506 were under rocks.

The adult female *Virginia valeriae* noted by Pisani (2005) in ground-level thatch of 2 m tall Conservation Reserve Program (CRP) grass focused attention upon the bias introduced by the unfavorable logistics of seeking small species in habitat that made collecting difficult. Bradford (1973) expressed a similar conclusion after his limited radioisotope tagging study of Missouri *Virginia striatula*. Thirty percent of his relocated snakes were in grass clumps and would have been missed by conventional collecting methods; Bradford remarked that the snakes were "stationary" in the grass, suggesting low vagility. In the tall, dense grassland habitat noted by Pisani (2005) — devoid of rocks of any size as observed during 2009 post-burn examinations — there would be almost no chance of a fortuitous collecting encounter.

This collecting bias, coupled with the secretive nature of *Virginia valeriae*, has resulted in most conclusions being based upon small sample sizes. Ahrens (1997) found *V. valeriae* only at his Camp Naish (Wyandotte Co., Kansas) site and recorded major habitat components as 45% herbaceous, 25% leaf litter, and just 5% rock. He trapped (drift fences and funnel traps) from May–October 1994 and for 25 days between June–July 1995, and so missed the entire spring emergence season. Fitzgerald (1994) attempted to derive a Habitat Suitability Index (HSI) for the species to be used as a conservation tool, but collected just 12 specimens and constructed the HSI using previously published records from diverse and often distant geographic areas. This approach constituted an obvious weakness in modeling resulting in her HSI corresponding to actual captures by just 55% (random chance).

Christiansen (1973) reported collecting 11 of 12 lowa *Virginia valeriae* in or near dense woodland, 9 of which he collected within 1000 ft of a stream. He concluded *V. valeriae* is "typically a woodland snake, most often found under stones . . ." and characterized the species' habitat in Iowa as "rocky woodland riparian or rocky woodland-meadow edge . . ." Intriguingly, Christiansen (2009, pers. comm.) also collected (Appanoose Co., Iowa, near the Missouri state line) two specimens between May–July from beneath boards in reseeded prairie grassland at least 500 ft from the edge of thin woodland. *Diadophis punctatus* was also present. Large Harvester Ant (*Pogonomyrmex occidentalis*) mounds were common in that habitat.

## METHODS

My study was concentrated in 5 hectares of the area in Jefferson County, Kansas, generally described in Pisani (2005, 2009), and had not been burned or hayed since being enrolled in the federal Conservation Reserve Program (CRP) and reseeded with warm-season grasses in 1988. From 1950 through 1987, the land was farmed with rotations of wheat and row crops. Crops during the 1981–1985 seasons alternated between wheat and soybeans. Successional upland woods adjacent to the grassland vary in species composition with slope aspect. Though leaf litter is thin, oaks are abundant, typical of an Osage Cuesta vegetation. In geology and overall characteristics, the site is not unlike the upland parts of the nearby (<1000 m) Fitch Natural History Reservation (Fitch 1965). Woodland just north of the grassland tract had little or no leaf litter and dry soil for much of the study period. It is included within habitat mapped as historically forested in the late 1850s by Government Land Office. A lightly-wooded hedgerow and fence line (both removed by bulldozing in 2006) divided the tract into two plots: a northern roughly rectangular area; and, a southern area approximating a right-triangle with the hypotenuse oriented to the southeast (Figure 1a). This bulldozed strip was ca 10 m wide, and quickly regrew in late 2006 and early 2007 with a mix of grasses and forbs typical of heavily disturbed habitats such as Musk Thistle (*Carduus nutans*), Sandbur (*Cenchrus pauciflorus*), Mullein (*Verbascum thapsis*), and Sunflower (*Helianthus annuus*).

In 2006, transects of paired (tin and wood) shelters (Parmelee and Fitch 1995; Wilgers and Horne 2006) were established at sampling stations (Figure 1b) through this primary tract. While some studies (cf. Ribiero-Júnior et al., 2008) have concluded that pitfall traps used with drift fences should be part of all herpetofaunal sampling, installation difficulties in the woodland and wooded edge habitat of parts of my study area, with a root-bound subsoil, weighed against their use. I installed transects of shelters in three principal habitats: Grass (in the CRP grass); Edge (at the edges of the woods—basically the drip line of the trees between Grass and Woods habitats); and Woods (10 m into the woods along the N and W edges of the north part of the site). These Woods shelter pairs were planned to provide comparison with their corresponding Edge pairs, and differences were present from the beginning, although only with greatly accumulated data did that become apparent. The woodland to the southeast of the site drops off along a rock

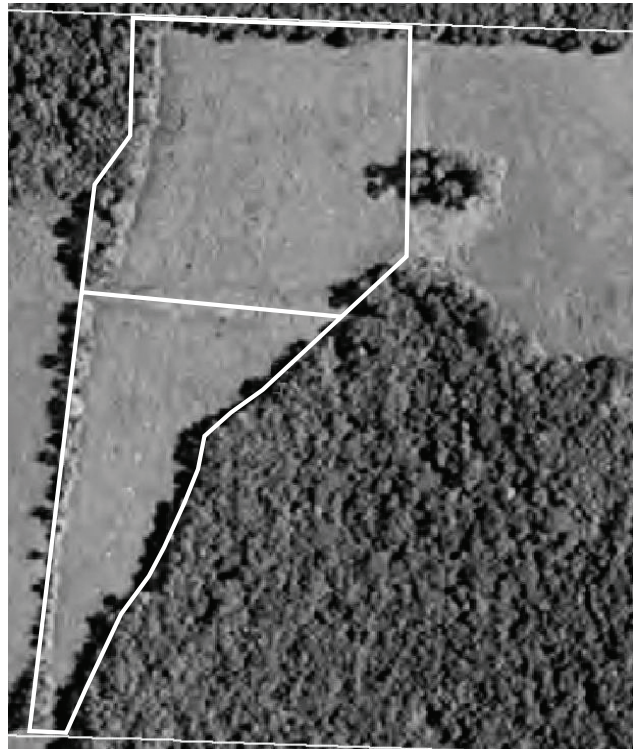


Figure 1a. Google Earth view of the study area (outlined in white) in Jefferson County, Kansas in 2008.

ledge that doesn't lend itself to shelter sampling; only Edge stations were established there. Stations were spaced at approximately 20 m intervals as topography allowed. Rock turning, rakes, and other potentially destructive sampling methods were not used to seek snakes.

From September–November 2006 and March–November 2007, 166 shelters were checked several times weekly for a total of 12,600 shelter-samples. This frequency continued March–May 2008 (172 shelters, 4816 shelter-samples), after which sampling effort was reduced. In May 2007, a transect of 8 plywood Grass shelters was extended into a similarly-vegetated secondary tract west of the main study area, and in March 2008 six woodland stations (two rows of three sets of paired shelters, extending 60 m N) were added to the north-edge Woods array in the primary tract. Total number of snake records from 2006–2007 was in excess of 3,000; all herpetofauna observed were recorded. All snake species except *Diadophis punctatus* and *Agkistrodon contortrix* were captured, processed (snout-vent length, tail length, mass, etc), marked with a unique scale clip, and released within minutes at point of capture.

Stations were georeferenced with a Garmin eTrex GPS (NAD83 datum). Sampling times were varied to minimize the considerable effects of microclimate bias attendant to artificial shelter sampling (Parmelee and Fitch 1995; Grant et al. 1992; Pisani this paper). Because most of the small species forming the focus of this study are of similar size, the potential for mechanical bias of artificial shelters (e.g., under-shelter clearance for snakes of different body size) was deemed minimal.

Temperatures beneath representative shelter pairs

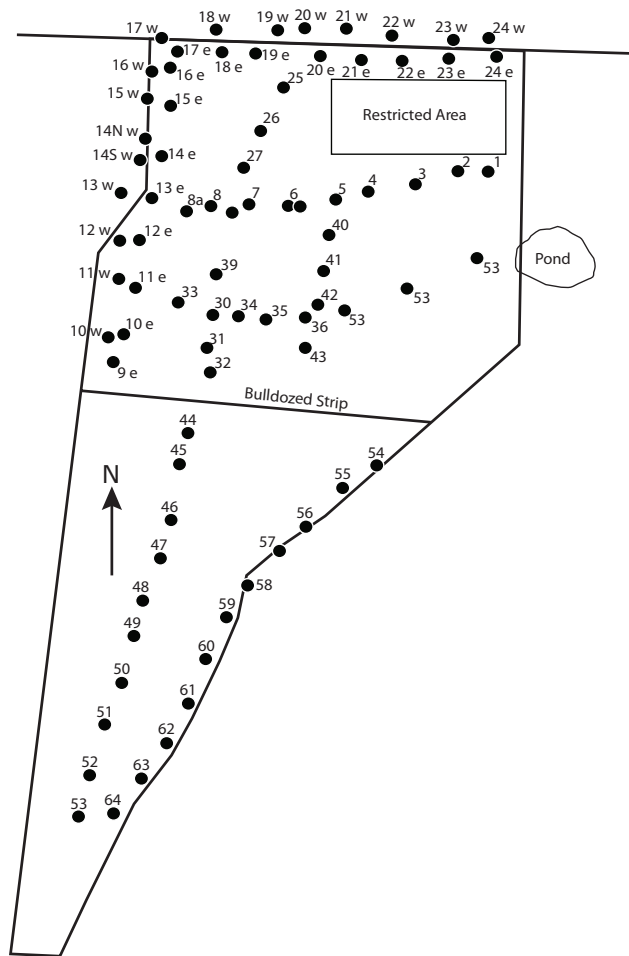


Figure 1b. Diagrammatic map of the study area in Jefferson County, Kansas in 2008, showing the numbered locations of each of the sampling sites.

were recorded each sample day with an Electro-Therm digital thermometer (SH66A, Cooper Instruments). An attempt was made to record relative humidity (rH) beneath representative shelter pairs using Beckman gypsum block sensors, but this was quickly judged to be inadequate. In May 2008, funding allowed purchase of ten HAXO-8 temperature/relative humidity dataloggers (MicroDAQ Co., Contoocook, NH 03229), which were installed beneath representative shelter pairs and in adjacent natural habitat. These were programmed to record 4 times daily (midnight, 6AM, noon, 6PM) through the end of October 2008. Logger data subsequently were downloaded via a LTI data dock using proprietary software. Two dataloggers failed during the season, and two others showed signs of irregular function late in the season. Removal of these data points allowed analysis of 536 data points from loggers in 3 Grass microclimates (grass thatch, under adjacent tin, and under adjacent wood) and at (1 each) a Grass, Edge, and Woods station. General comparisons were made by ANOVA (Minitab).

Scats were collected opportunistically from *Diadophis punctatus*, *Storeria dekayi*, and *Virginia valeriae* with greater emphasis placed upon those from *V. valeriae*. Samples were

preserved in 95% ethanol upon collection, and examined microscopically thereafter. No attempt was made to quantify the amount of earthworms consumed per the methods of Kruuk and Parish (1981) or Wroot (1985) as these methods are imprecise by the admission of those authors.

Similarly, no attempt was made to identify earthworm remains in scats to species. Snakes typically may encounter several earthworm species in varying habitats as they move seasonally (James and Cunningham 1989; James 1988; Satchell 1983; Edwards 1983; Zicsi 1983). Worms of several surface-feeding genera (mainly *Lumbricus* and *Allolobophora*) comprise the typical fauna of nearby sites (Clark 1970) and previous research indicates that *Virginia valeriae*, *Diadophis punctatus*, *Storeria dekayi*, *Carphophis vermis* and *Thamnophis sirtalis* feed opportunistically on these, with prey size relative to snake size affecting their choice, especially in smaller size classes (Cervone 1983; Fitch 1982, 1999). The vertical distribution of earthworms varies with season, age (and hence size) of worm, and species (Pearce 1983), all of which affect vulnerability to snake predation.

*Virginia valeriae* and *Storeria dekayi* population sizes were estimated from mark-recapture data with Simply Tagging software (Version 2.0.1.27, 2009, Pisces Conservation, Ltd., Hampshire, UK.) using the Chao model for closed populations with temporal change in capture probability. This model is mathematically more rigorous than the original Schnabel method (Henderson, et al. 2009). Morphological data were Log-transformed prior to analysis.

The few biopsies performed in the field for suspected subcutaneous parasites were formalin preserved and later sent to Dr. Stephen Goldberg (Whittier University, California) for examination.

Species occurrence was scored as Woods, Edge, or Grass depending upon the transect in which a snake was observed. Overall habitat use then was evaluated using the percent distribution of shelter stations among these transects (Grass: 46%; Edge: 34%; Woods: 20%), noting the Observed habitat use of a species overall, and comparing (Chi-square) these observations to Expected numbers based upon station distribution.

## OBSERVATIONS AND RESULTS

### Morphology

Male and female *Virginia valeriae* were highly sexually dimorphic in their relative tail lengths (Table 1a), as is typical for small natricid species. Adult female snout-vent lengths (SVL) were significantly longer than those of adult males (Table 1b). Regressions of male vs female mass on SVL showed no clear sexual dimorphism, and doubtless was affected by the presence of embryos seasonally and/or of food.

Morphological data for *Storeria dekayi* were equivalent to those of the species from nearby habitats as summarized by Fitch (1999).

### Habitat and Species Associations

Fifteen herpetofaunal species were observed to utilize the Grass habitat (Table 2). Of these, the most frequently observed were *Carphophis vermis*, *Diadophis punctatus*,

Table 1a. Adult *Virginia valeriae* male vs. female ratio of tail length to total length (TTL).

	Mean TTL	Range	
Males ( <i>n</i> = 20)	0.183	0.146-0.204	F = 103.3849 <i>p</i> = 0.0001
Females ( <i>n</i> = 29)	0.143	0.120-0.170	

Table 1b. Adult *Virginia valeriae* male vs. female snout-vent length (SVL in mm).

	Mean SVL	Range	
Males ( <i>n</i> = 20)	217.8	200–244	F = 5.9795 <i>p</i> = 0.0179
Females ( <i>n</i> = 29)	282.8	225–320	

*Storeria dekayi*, *Thamnophis sirtalis*, and *Virginia valeriae*. Results of sampling conducted in 2008 were in accord with 2006–2007; the study is ongoing. Clark (1970) studied a species assemblage associated with *C. vermisi* in habitat just 500 m southeast of my study tract; while nine of the species commonly observed in my study were the same (Table 2), there were notable differences. In particular, *Gastrophryne olivacea*, *Plestiodon fasciatus*, and *Agkistrodon contortrix* (major individual components in Clark's species assemblage) together comprised a minor component of the assemblage in the Grass habitat. Clark described his study area as being mostly rocky wooded slopes. The elapsed 36 years since Clark's published results limits the conclusions that can be drawn from these comparisons.

Table 3 and Figures 2a-d indicate far more frequent overall use of Grass habitat by several species than was predicted from earlier published accounts. This use was highly seasonal, with clear patterns. In particular, station data and snake recapture records showed the early emer-

Table 2. Species commonly recorded from Grass habitat, 2006–2008 (\* also noted by Clark 1970).

<i>Agkistrodon contortrix</i> *	<i>Ophisaurus attenuatus</i>
<i>Anaxyrus americanus</i> *	<i>Pseudacris maculata</i>
<i>Carphophis vermisi</i> *	<i>Plestiodon fasciatus</i> *
<i>Coluber constrictor</i> *	<i>Scincella lateralis</i> *
<i>Diadophis punctatus</i> *	<i>Storeria dekayi</i>
<i>Gastrophryne olivacea</i> *	<i>Thamnophis sirtalis</i>
<i>Lampropeltis calligaster</i>	<i>Virginia valeriae</i>
<i>Lampropeltis triangulum</i> *	

gence of *Virginia valeriae* at woodland and edge stations followed by their dispersal into Grass habitat by mid-April. All of the Woods and Edge records occurred either March–April or September–October. This indicates considerably more complex habitat utilization by *V. valeriae* than previously recognized.

*Diadophis punctatus*, *Storeria dekayi*, and *Carphophis vermisi* followed this pattern as well.

*Diadophis punctatus* occurred far less frequently at Woods stations than predicted by simple reflection of shelter distribution. Fitch (1982, 1999) categorized *D. punctatus* as primarily an edge species, though it occurs in diverse habitats. While I did not attempt to mark individual *D. punctatus*, when shelter records are viewed diagrammatically by week it was apparent that *D. punctatus*, like *Virginia valeriae*

Table 3. Habitat utilization by selected species, all records (not adjusted for seasonality), September 2005 through October 2008.

Paired Shelter distribution
Grass: (46%)
Edge: (34%)
Woods: (20%)
<i>Carphophis vermisi</i> (111 observations)
Grass: 37 (33)%, Expected = 51
Edge: 56 (50)%, Expected = 38
Woods: 18 (16)%, Expected = 22
DF: 2, Chi-sq 13.10, <i>p</i> = .0014
<i>Virginia valeriae</i> (92 observations; includes 2005 female)
Grass: 32 (35)%, Expected = 42
Edge: 43 (47)%, Expected = 31
Woods: 17 (18)%, Expected = 18
DF: 2, Chi-sq 6.533, <i>p</i> = .0381
<i>Storeria dekayi</i> (122 observations)
Grass: 50 (40)%, Expected = 56
Edge: 36 (30)%, Expected = 41
Woods: 36 (30)%, Expected = 24
DF: 2, Chi-sq 5.4144, <i>p</i> = .0667
<i>Diadophis punctatus</i> (2779 observations)
Grass: 1557 (56.0%), Expected = 1278
Edge: 1057 (38.0%), Expected = 359
Woods: 165 (6.0%), Expected = 555
DF: 2, Chi-sq 1432.743, <i>p</i> = .0001
<i>Thamnophis sirtalis</i> (107 observations)
Grass: 33 (31%), Expected = 49
Edge: 51 (48%), Expected = 36
Woods: 23 (21%), Expected = 21
DF: 2, Chi-sq 12.343, <i>p</i> = .0021

and *Storeria dekayi*, showed a clear pattern of use of Edge habitat during early March, moved into the Grass habitat from Edge and Woods stations by mid- to late March, and then retreated to Edge and Woods habitats in Fall. By late October, they were absent at Grass stations. By late March, *D. punctatus* was common at all stations and remained the most frequently encountered species at Grass stations through summer. *Diadophis punctatus* far outnumbered (Table 3) all other species studied in this population. This is consistent with Fitch (1975).

Clark (1970) refers to this seasonality in passing, saying that "unpublished data [from FNHR] ...show *Diadophis* to be wide ranging and a common inhabitant of grasslands during the summer months," and also (p. 106) that the "drop in frequency of observation [within *C. vermisi* habitat] of Ringnecks in May is probably due primarily to their moving out into other areas, while the rise in October is due to their return."

Fitch (1982) categorized *Storeria dekayi* as an edge species, *Carphophis vermisi* as primarily a forest one, and *Thamnophis sirtalis* as aquatic-riparian. In the present study, seasonally pooled *S. dekayi* records occurred across all habitat types with no significant difference from shelter distribution (Table 3). Fitch (1999) later indicated that this species seemed to avoid only grazed pasture with very short vegetation height, and inferred that it preferred "dense vegetation in damp places."

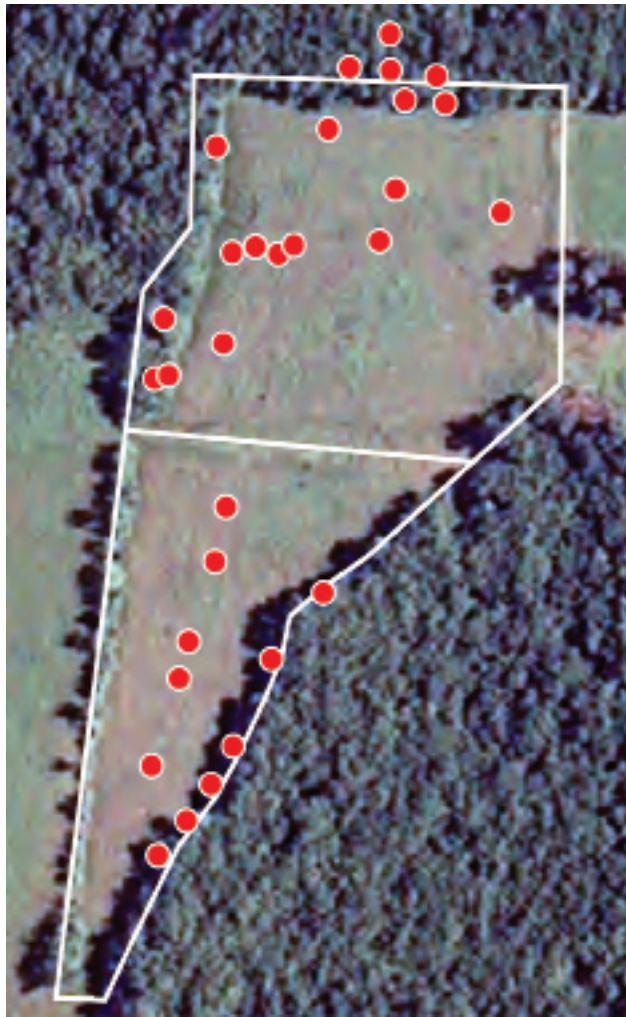


Figure 2a. Circles show capture stations during 2006–2007 for *Virginia valeriae* at the study site in Jefferson County, Kansas.

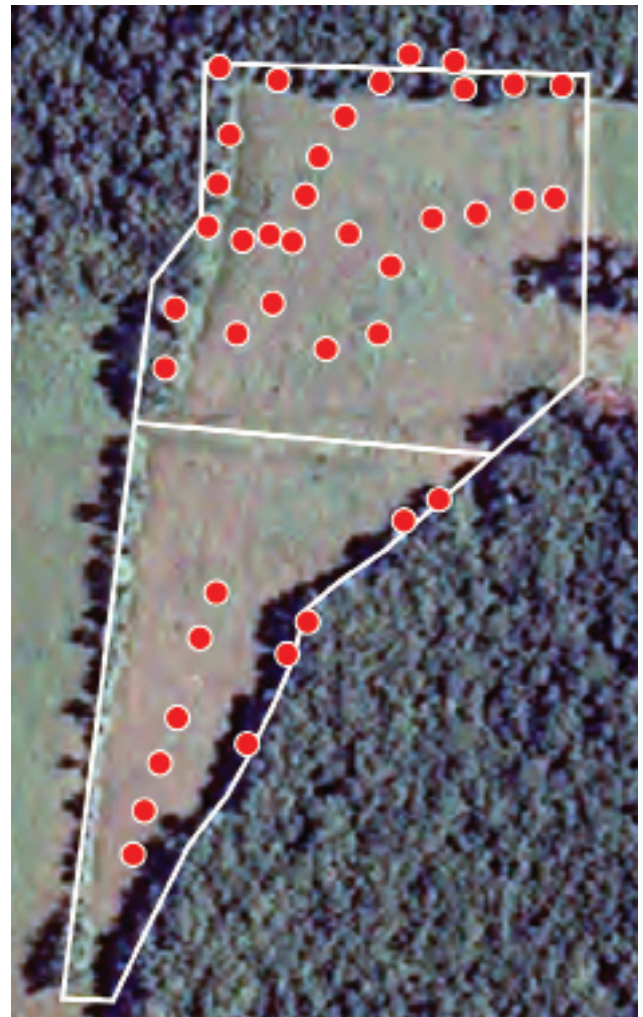


Figure 2b. Circles show capture stations during 2006–2007 for *Storeria dekayi* at the study site in Jefferson County, Kansas.

All of Clark's (1970) *Carphophis vermis* collecting sites were characterized by rocky, wooded slopes or (Clark 1970: Plate 4) one site with mixed grass-woody vegetation and evidence of previously wooded habitat. While most of my observations of *C. vermis* conform to habitats noted by Clark (1970), the species was commonly recorded in the Grass habitat (Table 3, Figure 2c), which was surprising to Fitch (pers. comm) during several collecting rounds.

A pictorial "flip book" of seasonal use of the different habitat types by the species discussed here is available at

<http://people.ku.edu/~gpisani/flipbook.pps>

#### Movements and Recaptures

Recaptures of marked snakes (*Virginia valeriae* and *Storeria dekayi*) allow some conclusions to be drawn about seasonal habitat use as well as site fidelity and to a lesser extent home range. This last is the most elusive when sampling with shelters, as encounters with animals rely far more on chance than when using techniques such as tantalum

tagging (Clark and Fleet 1976). Not only does home range commonly vary in snakes by species, but also varies within species by sex, age and season, making generalities at best weak and at worst terribly misleading. My approach here, therefore, will be very conservative and will omit the seemingly traditional drawings of circles and polygons with attendant statistical manipulation of sparse data.

#### *Storeria dekayi*

Fitch (1999) felt that *Storeria dekayi* demonstrated greater vagility than *Diadophis punctatus*, and also noted that population size was hard to estimate; of 172 marked specimens, he found just 3 recaptures (Table 4) from 1948–1997. He remarked (p. 111) that capture "[R]ecords . . . have averaged less than five per year during the decades of the study." A limited radiotagging study indicated that daily movements greater than 30 m were common. Snakes in his study were generally active from mid-March to early November.

In the present study between September 2006 and No-

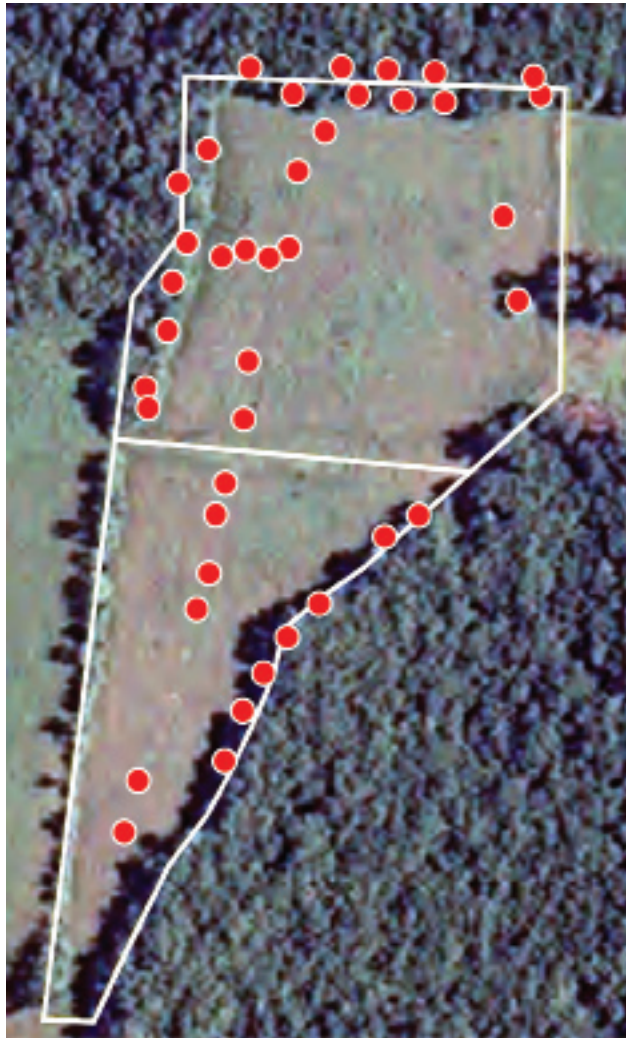


Figure 2c. Circles show capture stations during 2006–2007 for *Carphophis vermis* at the study site in Jefferson County, Kansas.

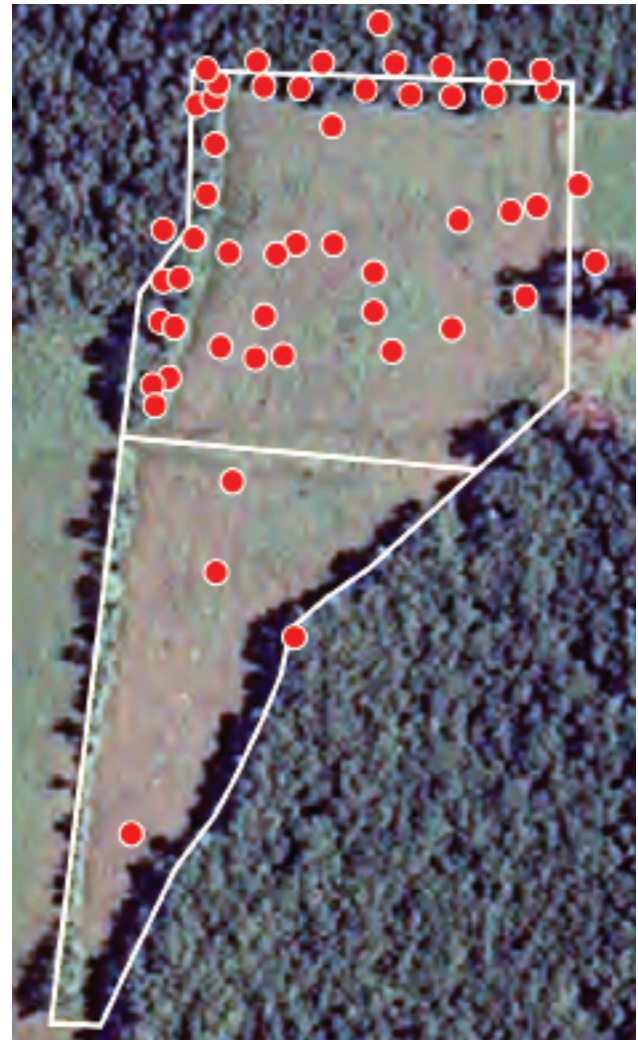


Figure 2d. Circles show capture stations during 2006–2007 for *Thamnophis sirtalis* at the study site in Jefferson County, Kansas.

November 2008, I marked a total of 89 *Storeria dekayi*, with 32 recaptures after first capture and observed 3 escapes (habitat recorded) for a total of 124 records. *S. dekayi* consistently has been among the first species to emerge from hibernation, and often was the first — the earliest noted activity date in 2009 was 10 February (Pisani and Pittman 2009). Average movement distance of males and females was similar (Table 5) and roughly comparable to the estimate provided by Fitch (1999). Most recaptures involved movements of less than 30 m.

Seven (3 female, 4 male) of 19 *Storeria dekayi* with multiple recaptures were encountered at the same shelter station, often for prolonged periods of time (Appendix 1). For example, a 216 mm (SVL) gravid female was recorded at the same Grass tin five times in 2007 (June 14, 16, 29; July 6, 8) — no doubt having found a site with temperature favorable to embryonic development. Another female (255 mm SVL) with five recaptures, first encountered (9 November 2006) at a Woods shelter on the west side of the tract, was recaptured at a Woods shelter 20 m N (16 May 2007), and was visibly gravid at that time. She remained at that

shelter until 19 May and on 25 May was captured 110 m N beneath an Edge tin on the N side of the tract. In 6 days she had gained 16% in mass. It is unknown if she fed in this interval — I felt that palpating for food would have damaged developing embryos, and so didn't.

The longest movements of male *Storeria dekayi* (190 mm and 215 mm SVL, respectively) were 125 m from an Edge to a Grass shelter between 10 March and 17 May 2007, and 50 m from an Edge to a Grass shelter between 17–27 March and 17 April 2007.

These males came from opposite directions and were captured 17 April at the same Grass station used by the 216 mm SVL gravid female described above. The female was not observed that date and may not have been in the vicinity. She also could have been concealed in thatch beneath the shelter or adjacent to it.

Most same-station recaptures were the next day or within 3 days, and many were associated with fall and spring aggregations at or near an active nest of ants (*Formica subsericea*) used as a regular hibernaculum by several snake species (Pisani 2009).

Table 4. Movements of marked *Storeria dekayi* (from Fitch 1999).

Date	Interval and distance
Date not given	Next day about 15 m
Date not given	386 days, 60 m
2nd year male 4/16/66	19 days later, 37.5 m

#### *Diadophis punctatus*

Fitch (1975) provided an extensive overview of movements in this species, and recorded movements up to 70 m in 1–5 day intervals. He noted a general trend towards progressively longer distance moved with increased time between captures, and suggested that over time different snakes were fluid in their use of habitat. This species shows pronounced aggregative tendencies (Dundee and Miller 1968) not observed in *Virginia valeriae* or *Storeria dekayi*.

#### *Virginia valeriae*

Forty-eight *Virginia valeriae* were marked in the 2006–2008 study interval, with 46 recaptures after first capture for a total of 94 records. Sixteen snakes were recaptured one or more times and in various habitats (Appendix 1). Most recaptures (69%) involved snakes at the same station, and as with *Storeria dekayi*, often occurred over prolonged periods of time. A large female (315 mm SVL) was captured 14 times between mid-March and mid-April 2007 beneath plywood at the same Edge station in the northwest corner of the tract. A 205 mm (SVL) male was recaptured 8 times at the same Edge station on the north perimeter of the tract.

Two males (SVLs 212 mm, 203 mm) moved a considerable distance, both during spring 2007; these movements could have been associated with mate searching, though that is unproven. These movements were, respectively, 65 m SE from an Edge to a Grass shelter between 10 March and 25 March 2007 (after remaining at that station March 26th and 29th the snake was encountered at another Grass station 100 m west on April 3rd), and 45 m S from one Grass shelter to another between 16 March and 21 March 2007 (this male again was encountered at that Grass shelter on 23 March).

Two females (SVLs 295 mm, 320 mm) moved (60 m S and 20 m W, respectively) between Grass shelters during April–May 2007. Though the moves were to the same shelter (Grass Station 8), the snakes were not observed together.

Based upon these limited records, males seem to move more than females during spring, possibly associated with mate searching, as is typical of natricid snakes in general. The high percentage of same-station recaptures seems principally to be due to snakes leaving or returning to hibernacula. When only males (for which same-station recapture dates are comparable) are compared, the data suggest that *Virginia valeriae* is a less vagile species than *Storeria dekayi*. However, the numbers are too small to compare statistically with any degree of confidence in the biological significance of the results.

Todd et al. (2008) summarized 36 years of data on the eastern race of *Virginia valeriae*, which were collected in

Table 5. Average movements of *Storeria dekayi* (this study).

Females	Mean = 55 m (20–150 m), $n = 6$
Males	Mean = 48 m (20–100 m), $n = 6$
n.s. paired <i>t</i> -Test, $p = 0.3657$	

South Carolina using several methods. Of 222 marked *Virginia valeriae valeriae*, only one female was recaptured. Their data plus other studies of *V. v. valeriae* suggest a bimodal (spring, fall) activity season for this eastern race, though they indicate that snakes were "frequently captured in all warm months." While abundance of *V. valeriae* and *Storeria dekayi* in my study could be described as bimodal (Figure 3a,b), it is unclear (see below — datalogger analyses) if this is simply an artifact due to a less attractive microclimate beneath shelters during warmer months. Also, Todd et al. (2008) used pooled data from multiple collection methods gathered over a greater time span which undoubtedly decreases collecting bias.

What is apparent from Figure 3a,b is that the proportion of male *V. valeriae* observed in my study decreased markedly in April and May, becoming more nearly equal again in October and November. For *S. dekayi* this decrease in male captures occurred a month later. I believe that this reflects affinity of gravid females for the relatively warmer microclimate beneath shelters during late spring and early summer, making them more likely to be observed.

Reproductive mode may also affect seasonal shelter use. In contrast with the oviparous *Carphophis vermis*, which was captured during all March–October months except August (Figure 3c), no *Virginia valeriae* (viviparous) were captured during July–August. For *Storeria dekayi* (also viviparous), this gap in the data occurred August–September. Since most *V. valeriae* and *S. dekayi* summer records were of gravid females, it is possible that these snakes sought cooler microclimates in which to deliver litters. Soil beneath several Grass shelters and adjacent thatch typically dried during summer, with deep cracks evident. These cracks would have afforded ready access to a presumably cooler microclimate, though it is not known if snakes used them. More reclusive female behavior during birthing also may

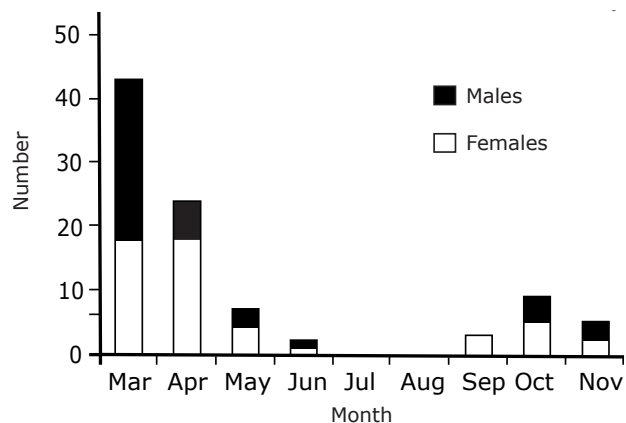


Figure 3a. Captures of male and female *Virginia valeriae* by month during 2007 (no captures in July–August).

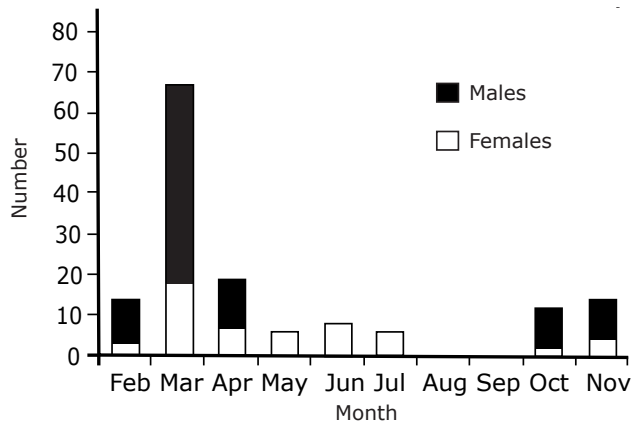


Figure 3b. Captures of male and female *Storeria dekayi* by month during 2007 (no captures in August–September).

reduce predation risk to neonates. As noted below (Temperature Relations), *V. valeriae* and *S. dekayi* are not only cool-tolerant, but (except for gravid females) seem to have lower preferred body temperatures than other species.

#### *Carphophis vermis*

Fifty-eight *Carphophis vermis* were marked, with 52 recaptures after first capture (most at same place) for a total of 110 records.

Of 16 snakes with multiple recaptures, 10 (2 male, 8 female) were at the same shelter and 2 others (1 male, 1 female) differed by 10 m between capture points. One of these latter (female, 290 mm SVL at first capture, 305 mm SVL at last capture) was caught (on 8 and 16 May 2007 plus 1 May 2008) at the same Edge station. On 7 September 2008, she was again observed 10 m N at a Woods station.

Another female (332 mm SVL) was recorded at the same Woods shelter 12 times between 9–23 March 2007. On 9 April 2008, she was collected at an Edge station 60 m north of her 2007 records and was again observed (17 April 2008) 40 m east at a Grass station. A third female,

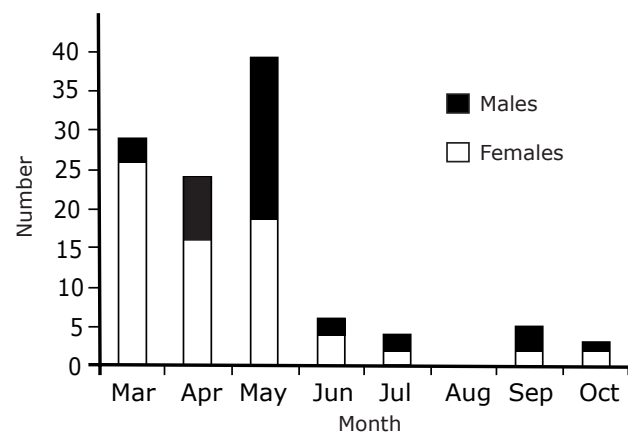


Figure 3c. Captures of male and female *Carphophis vermis* by month during 2007 (no captures in August).

328 mm SVL, recorded (26 and 27 March 2007) at an edge station 20 m N of the female mentioned above had by 19 April moved to a Grass station 45 m NE where she also was captured on April 24th, 28th, and May 8. A male (267 mm SVL) observed at a Grass station 24 April 2007 was in 2008 observed twice (May 8, 12) 90 m N at an Edge station.

As with *Virginia valeriae*, these data are insufficient to provide any biologically significant home range or sexually differentiated movement generalities, but all (Appendix 1) are consistent with data for resident snakes (as opposed to his introduced ones) in Clark's (1970) study of this species.

#### *Thamnophis sirtalis*

While not a principal focus species for this study, 82 *Thamnophis sirtalis* were marked, with 36 recaptures after first capture. Four escaped capture (habitat recorded), and in 2006 eleven were released unmarked (habitat recorded) for a total 123 records. Unsurprisingly (cf. Fitch 1999), *T. sirtalis* was far more vagile than *Virginia valeriae*, *Storeria dekayi*, or *Carphophis vermis*. Only 2 of 7 males (both ca 430 mm SVL) and no females were collected at the same shelter multiple times (Appendix 1). Male versus female movements ( $n = 18$  versus 5) were not statistically different (67.8 m range 20–180 m, and 83 m range 20–120 m; s.e.± 14.5 and 10.7) in this small sample.

*Thamnophis sirtalis* having incomplete tails (6 of 32 male: 4 of 50 female) ranged from 420–570 mm SVL. Fitch (1999) discussed tail autotomy as an anti-predator mechanism in *T. sirtalis*.

#### Food and Feeding

The earliest defecations observed (2007) during field handling were: *Virginia valeriae*: March 16 and 26; *Storeria dekayi*: March 17 and 23. The earliest collection date (both species) was March 10, indicating that by 1–2 weeks after emergence snakes were feeding.

Fitch (1975:24) cited his own data and that of others to estimate that the average residence time of an earthworm meal in *Diadophis punctatus* was ca. 4 days at 25°C. Comparable data on *Storeria* and *Virginia* are not available, but this estimate seems reasonable for these genera at similar temperature regimes. Thus, it can be inferred that snakes in the present study began successful foraging and digestion very soon after emergence from hibernation.

The diet of *Virginia valeriae* ( $n = 12$  scats) collected in this study consisted solely of earthworms. Scat samples from *Storeria dekayi* ( $n = 6$ ) contained earthworm setae in all but one sample which contained unidentifiable exoskeletal remains. This is consistent with previously published research with these species (Fitch 1999; Cervone 1983). Several *D. punctatus* scats ( $n = 5$ ) were also collected opportunistically during March 2007. Most identifiable material indicated a diet of earthworms (consistent with Fitch 1975); one sample contained unidentifiable exoskeletal fragments.

Scats containing setae also contained considerable amounts of soil and partially digested plant material consistent with an earthworm diet.

Bradford (1973) observed one wild-caught male *Virginia striatula* in the act of consuming eggs of an unidentified species of ant, and remarked that "[a] few ants were on the snake but did not appear to have been biting him." All other *Virginia* in Bradford's study consumed earthworms. While *V. striatula* is a species distinct from *V. valeriae*, given the close association with ants noted for *V. valeriae* it is not impossible that this species (especially juveniles for which data are especially lacking) also on occasion consumes ant eggs and/or pupae.

### Endoparasites

Observed incidences of endoparasitism were low. One adult *Storeria dekayi* (of 6 scats from that species) contained rhabditiform larvae (Goldberg pers. comm.) that could not be identified to genus. Similarly, one of 12 *Virginia valeriae* scats contained rhabditiform larvae. Three other *V. valeriae* and one *S. dekayi* were observed with soft, subcutaneous masses. These were biopsied in the field. The contents tentatively were identified as metacercariae, but no further identification could be made (Goldberg pers. comm.).

### Temperature and Humidity Relations

#### *Environment from Dataloggers*

Deployment in this study of a relatively small number of dataloggers was insufficient to provide any detailed characterization of habitats across the study tract. However, one valuable pattern observed involved relative humidity (rH) at Station 40, a representative Grass station (Figure 1b; Table 6). ANOVA analysis of datalogger humidity records evaluated differences among environments and times of day while removing the variation among days. This indicated that ground level grass thatch at this station was consistently more humid than either of the shelters (tin or wood). Wood was consistently the least humid, but tin was insignificantly different from grass at night and in early morning; this latter condition perhaps was due to a condensation effect beneath tin as it cools, whereas wood has a tendency to absorb moisture as well as release it. A significant interaction term indicated that the differences among environments differed with time of day. Also, the residuals from these models were autocorrelated, meaning that the standard errors are gross underestimates. This did not affect the overall pattern to the humidity data, nor did it affect the means.

As elaborated in sections above and below, these data suggest that the apparent seasonal bimodality of activity I observed for *Virginia valeriae* and *Storeria dekayi* may simply be an artifact of shelter sampling. These species may very well have been in the more humid natural habitat adjacent to a number of shelters where I observed them at various times during summer.

A second 2-way ANOVA was used to compare (Table 7) humidities at ground level in natural habitat at three different stations: 40 (a Grass station), 60 (an Edge station largely shaded from morning sun), and 22 (an Edge station generally exposed to sunlight from 9 am to sunset). Humidity varied with both site and time of day, but there was no interaction, indicating that basically the differences among

Table 6. ANOVA for humidity at Station 40 beneath tin and wood shelters vs. adjacent grass thatch. All data pooled (rH-p) and pooled by time-of-day hour (TOD).

	Means				
	<i>n</i>	rH-p (%)	TOD	<i>n</i>	rH-TOD (%)
Grass	536	93.594	0000	402	86.518
Tin	536	86.101	0600	402	86.065
Wood	536	62.818	1200 1800	402 402	74.252 76.515
Source	DF	SS	MS	F	P
Gr_Tn_Wd	2	276103.4	138051.7	250.46	0.000
Time of day	3	48898.8	16299.6	29.57	0.000
Gr_Tn_Wd (x Time of day)	6	28589.8	4765.0	8.64	0.000
Day	133	262668.8	1975.0	3.58	0.000
Error	1463	806401.8	551.2		
Total	1607	1422662.5			

S = 23.4776 R-Sq = 43.32% R-Sq (adj) = 37.74%

sites were consistent for all four times and the differences among times were the same among all sites. Unsurprisingly, the graphs show that at all locations humidities were highest at dawn and midnight and lower at 6 pm and noon. Tukey 95% Simultaneous Confidence Intervals (All Pairwise Comparisons among Stations and Times) confirmed patterns evident in the ANOVA. While these particular pooled data are well within the range recorded by other authors for these snake species, the analyses again suggest the need for caution (at least when sampling with shelters) in ascribing seasonally bimodal snake activity based upon bimodal observational data.

Seasonally pooled temperature data beneath wood shelters at three stations with different exposures were compared using 2-way ANOVA. Temperature varied with both site and time of day, with a significant interaction, indicating that the differences among the sites depended upon time of day (lower at midnight and 6 am; higher at noon and 6 pm). While statistically significant, these pooled data are of minimal biological meaning, as gross variation in pooled temperature was less than 3°C and no snake sampling was conducted between 6 pm and 6 am. Daily and seasonal temperature cycles were more important to locating snakes beneath shelters (see models in Grant et al., 1992).

#### *Temperature, Humidity and Snakes*

Because temperatures beneath tin and wood shelters tended to be considerably warmer than air temperatures (thus affecting snake body temperatures, Tb) during most sampling periods, no attempt was made to record Tb of captured snakes, nor to draw conclusions about minimum activity temperatures. However, as noted above, *Virginia valeriae* and *Storeria dekayi* consistently were the earliest species observed to be active. While specimens of *Diadophis punctatus* and *Carphophis vermis* also were observed during the first week of March 2007, *D. punctatus* did not reach a level of activity comparable to that of *V. valeriae*

or *S. dekayi* until the third week of March, followed a week later by *C. vermis*.

Data from this and other studies indicate that *Virginia valeriae* is relatively cold-tolerant, and is active at temperatures inhibiting activity in most other genera. Fitch (1956) reported the captive survival and activity of a juvenile *V. [Haldea] valeriae* at near-freezing temperatures that were fatal to *Diadophis punctatus* housed with it. Cervone (1983) recorded adult *Virginia v. pulchra* active in March, and in April recorded body temperatures for both sexes of 8.6–8.8°C. Fitch (1975) noted one low activity temperature for *D. punctatus* of 11.7°C, with most lower-level readings around 15°C. The majority of his records clustered between 26–30°C (mean 26.6), with most *D. punctatus* having a Tb above ambient. Clark (1970) indicated that *Carphophis vermis* had a broad range of activity temperature, and cited Fitch (1956) "average and maximum body temperatures [of *C. vermis*] were markedly lower than those of any other kind of reptile studied." While activity of these species generally occurred later than that of *Storeria dekayi* or *V. valeriae*, in 2007 an adult female *C. vermis* and a juvenile *D. punctatus* were the first two snakes I observed (on March 9).

By late March in this study, *Diadophis punctatus* commonly were recorded beneath shelters in grass and edge habitats, and by late April they were the dominant species recorded beneath shelters in all habitats, especially when shelters were checked in the afternoon (when temperatures were highest). Temperatures recorded in grass thatch ca. 2 cm beneath shelters, receiving even indirect insolation, not unexpectedly exceeded nearby air temperatures. In early March, the difference by 1300 hr CST would commonly be ca. 12°C higher beneath tin and 4°C higher beneath wood at the Edge transects, and by early April 2007 these differences at the same general time of day could exceed 14°C. *D. punctatus* of both sexes and several age classes not uncommonly were found beneath shelters when April temperatures exceeded 31°C. By early June, when (raw data from Loggers) mid-day temperatures beneath Grass and Edge tin and wood regularly reached 35°C or above, no herpetofauna were observed beneath shelters, whereas if transects were checked in early morning up to 1000 hrs CDST, *D. punctatus*, *Thamnophis sirtalis*, and *Coluber constrictor* would predictably be seen, and to lesser extent *Storeria dekayi* (almost all female and most gravid). Collecting time plus cloud cover and air temperature combine

Table 7. Datalogger humidity variation by station (Woods, Edge, and Grass) and time-of-day. SD = standard deviation.

Individual 95% confidence intervals for mean based on pooled SD				
Station	Time	n	Mean	SD
22	6 am	134	99.11	3.17
22	6 pm	134	92.42	11.38
22	Midnight	134	97.97	4.89
22	Noon	134	90.97	12.62
40	6 am	134	97.05	9.70
40	6 pm	134	91.69	13.50
40	Midnight	134	97.57	7.73
40	Noon	134	88.07	20.65
60	6 am	134	97.67	6.48
60	6 pm	134	89.76	17.59
60	Midnight	134	96.68	7.37
60	Noon	134	89.27	18.26

Individual 95% confidence intervals for mean based on pooled SD by time of day	
Time of Day	Mean
6 am	97.9450
6 pm	91.2913
Midnight	97.4057
Noon	89.4351

Individual 95% confidence intervals for mean based on pooled SD by station	
Station	Mean
22	95.1162
40	93.5938
60	93.3478

to introduce complex collecting bias when using shelters (Grant et al., 1992). In this study, such bias was minimized by varying collection times and shifting effort to early morning on May–August days with low cloud cover. Even so, observations of *Virginia valeriae* declined greatly between May–August. However, the few recaptures occurring during these months suggested that *V. valeriae* moved beneath nearby grass thatch where datalogger rH records were generally higher than under shelters. Cervone (1983) found gravid *Virginia v. pulchra* under rocks in areas of mean rH of 86.2% ( $n = 163$ , range 44–100%).

Sudden drops in temperature during early and late activity seasons resulted in some mortality. During my regular shelter checks, four dead *Diadophis punctatus* were seen in late October 2007, and one dead *Storeria dekayi* in April 2008. The snakes bore no sign of external injury; they presumably were killed by sudden temperature decreases the preceding evenings.

### Defense

Aggression in small snake species is poorly documented, with repellent musk being the most commonly reported defense mechanism. Thus, it is useful to collect here the very few observations of aggression in *Virginia valeriae*. Todd (2008) noted a threat display by a male (111 mm SVL) *V. v. valeriae* in South Carolina. Cervone (1983) reported that two gravid females of the closely related *V. v. pulchra* flattened their bodies, drew back lips and gaped when handled. In the course of my study, I noted one bite attempt by a female (236 mm SVL) on her 3rd capture in spring 2007.

While an anthropocentric view of aggression by such small species may consider such to be of questionable effectiveness in avoiding predation, effectiveness must be viewed in the context of potential predators. Fitch (1975) thoroughly reviewed the predators of *Diadophis punctatus*. As a number of those predators reach considerably greater mass than adults of any of the small snake species I observed, they must be considered potential predators of any small snakes, as well as juveniles of some others that attain large adult size. In all probability, the secretive nature of *Virginia*, *Storeria*, *Diadophis*, and similar-size species make many large predators reasonably infrequent threats to small snakes that spend most of their lives beneath plant litter. However, several small mammals quite common in the habitats reported here are potential predators on these snakes, of which the one with the largest (and presumably best developed) eyes is *Peromyscus leucopus*, noted by Fitch (1975) to prey upon *D. punctatus*. *P. leucopus* occurred in all habitats (with seasonal variation) in my transects. It therefore is not far-fetched that selection has preserved the lip curling and more overt aggressive display noted here and by other authors.

Additionally, when illumination allows, *Virginia* and some other small snake genera make extensive use of vision during predator encounters with other snakes (Pisani, unpublished), with both predator and potential prey keying upon the movements of each other. This raises the intriguing question of aggressive displays by adult or juvenile snakes also being effective, even momentarily, against attack by snakes or larger lizards.

Fitch (1975:23) discussed the euryphagous habits of the genus *Diadophis* throughout its range and remarked that it was therefore unusual for the large sample of *Diadophis* in his study to feed almost exclusively on earthworms. Fitch's study area and mine are contiguous, and it appears that earthworms are an abundant, nutritious food resource that in all but perhaps the driest periods are not a limiting factor (see for discussion MacDonald 1983). However, Christiansen (1973) mentioned finding one *Virginia valeriae* in the stomach of a *D. punctatus*. That specimen was collected "along a stream in a grazed woodland," and presumably had access to earthworms. Therefore the genus must be considered at least a potential, and abundant, predator of sympatric *Virginia* and *Storeria dekayi*.

### Reproduction

Fitch (1999: 112) described *Storeria dekayi* as "notable for early birth dates, made possible by cold tolerance with early emergence from hibernation." The few published records of birth dates for *Virginia valeriae elegans* throughout its range (Smith 1961, Dundee and Rossman 1989) and the closely related *V. v. pulchra* (Cervone 1983; Pisani 1971) suggest that the same applies to Kansas *V. valeriae*. Both Bradford (1973) and Fitch (1970) relied upon earlier-published records of *V. valeriae* births in early or mid-August.

While I collected juveniles of *Storeria dekayi* and *Virginia valeriae*, I hesitate to label these as neonates *sensu stricto*. I observed just one young-of-the-year *V. valeriae* in 2007—a female, 105 mm SVL, captured twice at a Woods station (on 29 September and 1 October). Another female (112 mm SVL) apparently of the 2006 cohort was collected at Grass Station 8 on 21 March 2007. At Station 8, I collected two gravid female *V. valeriae* (one of which also was recaptured) in May and June 2007; the 105 mm juvenile was collected not far away.

While no conclusions can be drawn from such a small number of snakes, both stations were on the northwest side of the tract, which features a shallow, northwest-facing slope. As such, it received less direct summer insolation than other exposures, though I did not include measurements of that in my study. It is possible that the exposure afforded a slightly cooler August temperature regime and may have been attractive to pre-parturient female *Virginia valeriae*, but this is speculative.

Bradford (1973) measured ten preserved neonate *Virginia valeriae* (5 males, 5 females) from Missouri that were collected during July–September. Exact localities were not given. Mean neonate SVLs did not indicate sexual dimorphism at birth (males 9.0 cm, females 8.6 cm). The earliest embryo Bradford observed was in a female collected May 11. Bradford's histological work indicated that sperm production peaked in July and that sperm were seen in female reproductive tracts in both March–April and September–October. I observed neither courtship nor mating in *V. valeriae* or *Storeria dekayi*, but Bradford's observations combined with Cervone's (1983) observation of spring and fall mating in *V. v. pulchra* suggest that Kansas *V. valeriae* may mate in spring or fall.

## Population Estimates

Fitch (1999) suggested a density of 42/hectare for *Storeria dekayi* but qualified the very tentative nature of this estimate due to the low number captured over 50 years. Fitch calculated that his captures, and therefore *S. dekayi* abundance, were only 3.3% of those for *Diadophis punctatus*. In this study, that value is 4.4% (24.4/hectare) for *S. dekayi* and 3.3% (18.3/hectare) for *Virginia valeriae*.

Analyzing the full individual recapture data for animals marked in this study indicates a density for *Storeria dekayi* close to Fitch's estimate: total population 160 (32/hectare), 95% confidence, range = 136–210, s.e. 18.22, mean probability of capture = 0.0206.

The corresponding analysis for *Virginia valeriae* is lower, though confidence limits of the two species overlap: total population 97 (19.4/hectare), 95% confidence, range 65–178, s.e. 27.2, mean probability of capture = 0.0171.

Fitch (1999: 112) noted that the vagility of *Storeria dekayi* was greater than that of *Diadophis punctatus*, and that this likely affected trap captures. *S. dekayi* seems also to be more vagile than *Virginia valeriae*; probabilities of capture are not significantly different in this study (unpaired t-value = 0.796,  $p = 0.4278$ ).

## DISCUSSION and CONCLUSIONS

The most common ophidian associates of *Virginia valeriae* observed in this study are *Diadophis punctatus*, *Storeria dekayi*, *Thamnophis sirtalis*, and *Carphophis vermis*. This corroborates observations by other authors for the species (or the closely related *V. v. pulchra*) in other parts of its range (Christiansen 1973; Cervone 1983).

Cumulatively, data from this study, others done by Fitch in adjacent tracts, and ones done in other parts of the range of these species indicate that *Virginia valeriae* and *Storeria dekayi* are active at cool temperatures, and are among the very first (if not the first) eastern Kansas snakes to emerge from hibernation. By early April, both species have dispersed from hibernation sites. Cool early March weather is often regarded as unsuited to snake collecting and observation, though it may in fact be optimum weather for locating species in these two genera.

Early emergence, relatively short gestation, and activity at temperatures lower than is optimum for sympatric small vermivorous snakes facilitates the early parturition typical of *Virginia valeriae* and *Storeria dekayi*. Additionally, neonate SVL and mass (as percents of those of the female parent) of both species are considerably greater than similar values for sympatric surface-feeding vermivorous snakes (Fitch 1999: 140; Cervone 1983: 147; Pisani 1971). Neonates grow rapidly in the first few months, and add at least 20 percent SVL by hibernation. These important resource partitioning elements headstart neonates of these species in having access to a critical, but more restricted, food resource (small earthworms) than is available to older snakes with concomitantly larger gape. Larger vermivorous snakes can (and not unexpectedly do) opportunistically consume a spectrum of worm size-classes (Fitch unpublished; Pisani unpublished). In this study, a 570 mm SVL female *Thamnophis sirtalis*, captured October 2007, disgorged an adult

*Pseudacris maculata* and 5 earthworms ranging in length from 3.8–7.6cm.

While several authors (c.f. Fitzgerald 1994) have stated that *Virginia valeriae* feeds at night, there has been no evidence presented that this is their sole behavior. While they very well may consume food at night, there is no reason to believe they would not forage at any other time as well. The dense grass thatch described in this study would seem to provide excellent refuge and foraging opportunity independent of time-of-day.

Fitch (1999) observed that Kansas *Storeria dekayi* neonates were larger than those from the state of Virginia (Mitchell 1994), which were 59 percent of the weight of Kansas ones. This could reflect different selection pressures affecting the two races of this widespread species, or could simply represent feeding success of particular females widely separated in time and place. No similar difference has been noted for *Virginia valeriae*.

In my study, both *Virginia valeriae* and *Storeria dekayi* made extensive use of tall grass habitat during their activity seasons. In particular, *V. valeriae* in this population made far more use of this habitat, seasonally, than previously reported. Woodland in this study was used primarily for available hibernation sites, with little occurrence of *V. valeriae* in woodland between April and September. This pattern most likely is associated with food availability. An observation of Fitzgerald (1994: 42) is instructive: *Virginia valeriae* "[c]apture success increased as canopy cover increased and decreased as [leaf] litter increased." Her site has high density of large oaks, and tannins may have reduced availability of earthworms. Satchell (1983) and Zicsi (1983) showed that in Europe oak litter was not a preferred earthworm food source for the lumbricid genera introduced in North America and common through eastern Kansas. This remains speculative, as Fitzgerald's sample size of 12 limited her conclusions.

Habitat within the rectangular north part of the tract was not uniform, which was correlated with occurrence of *Virginia valeriae*, *Carphophis vermis*, and *Storeria dekayi*. As can be seen in Figure 2a–d, no captures of these species occurred in the southeast corner of that tract, which had been invaded by woody species—mainly Blackberry (*Rubus ostryifolius*) and Coralberry (*Symphoricarpos orbiculatus*). This may have offered unfavorable microhabitat for small vermivores. The more generalist *Thamnophis sirtalis* often was captured there. Very few *T. sirtalis* (4 of 107 records 2006–2007) and no *Coluber constrictor* were observed in the triangular south part of the tract. This is peculiar given that these highly vagile species commonly were observed in the north part. Just one female *T. sirtalis* (470 mm SVL) crossed the ca 10 m disturbed strip between the two areas in 2006–2007, moving from the SE edge of the lower part to the general center of the grass in the north part in early October 2007. The earliest 2007 *T. sirtalis* records suggested that the majority of this species entered the area from the northwest corner of the tract where the topography drops off along a wooded, rocky, west-facing ledge. Fitch (1999) estimated average home ranges for adult *T. sirtalis* at ca 0.54 ha, and it is therefore possible that the home ranges of these snakes all were within the north area and adjacent woods.

The observation that no *Virginia valeriae*, *Carphophis vermis*, and *Storeria dekayi* recaptures occurred across the disturbed strip, despite abundant records north and south of it, suggests that even this small span of disturbed habitat served as an effective barrier to movement of these species. As part of ongoing prairie management of this and adjacent grassland tracts, the entire area was burned on 18 March 2009. Continued study should clarify some of these issues.

### Land management, Earthworms, and Snake Populations

Earthworms are an abundant, high quality food resource for many vertebrates, and though snake studies are lacking, mammalian studies indicate that earthworms of various genera provide a high-protein diet rich in essential amino acids (Mattson, et al. 2002; Sabine 1983).

Populations of vermivorous snakes are very susceptible to land use and management practices insofar as these affect established hibernacula and availability of earthworm prey. Northeast Kansas *Diadophis punctatus*, *Virginia valeriae*, *Carphophis vermis* and *Storeria dekayi* all feed predominantly on earthworms of various species. While *C. vermis* is a highly specialized burrower capable of active tunneling to forage, *V. valeriae* is far more a surface forager that opportunistically uses burrows and soil interstices. Cervone (1983) characterized the soil of *V. v. pulchra* habitat as loamy sand to clay well-drained soils (3.2-30.3% [mean 10.6%] soil moisture) that support persistence of underground tunnels. Cervone (1983) also kept *V. v. pulchra* adults on a variety of soils in the lab; none showed any tendency to burrow, instead remaining on the surface beneath available cover objects. While similar studies have not been done with *D. punctatus*, *S. dekayi*, or the other races of *V. valeriae*, the generally rounded, elliptical head shapes of these snakes suggest that they too are surface feeders.

The foraging success of surface-feeding vermivorous snakes is closely bound to the ecology (and hence vulnerability) of earthworms across habitats. The relationship between dense vegetative ground litter (especially grass thatch), availability of organic nutrients, and surface moisture on earthworm abundance at the surface is apparent from other studies. Uncultivated grassland supports up to three times the population of lumbricid worms than does cultivated soil (Lofs-Holman 1983), which was directly related to more available organic material in thatch. Other relevant aspects of worm ecology are that uncultivated grassland supports up to four times the population of lumbricid worms than does dry upland woods with minimal leaf litter and, as mentioned above, oak litter is less palatable to many genera of worms than is litter from plants lacking tannin (Satchell 1983; Zicsi 1983). I lacked time and resources to sample earthworm populations in the woodland adjoining my study area, but its characteristics warrant application of the observations of these authors. Reduced populations of surface-feeding worms may be expected to have concomitant effect upon foraging snakes in Woods transects.

Historical land use practices affect both abundance and diversity of earthworms. James (1988) found that in tallgrass prairie, biomass of native prairie species of earth-

worms (*Diplocardia*), which feed below ground, increased considerably with burning, while that of the surface-feeding introduced European *Aporrectodea turgida* decreased. Lofs-Holman (1983) indicated that burning greatly reduces thatch, which lowers lumbricid worm reproductive success (via much-reduced juvenile survival). Related studies (Edwards 1983) showed that regular cultivation destroys the upper parts of the relatively permanent burrows of adults of larger, surface-feeding worm species (*Lumbricus terrestris*, *Allolobophora* sp.) used as food by *Carphophis*, *Virginia*, and other eastern Kansas snakes. Setser and Cavitt (2003) found that *Thamnophis sirtalis* (largely vermivorous especially in younger age cohorts) was frequently observed in long-term unburned Kansas prairie but was not in burned tracts until late in the season after grass cover had regrown. They suggested increased predation risk and less favorable thermal regimes in burned vs. unburned tracts as potential reasons for their results, and certainly these factors are operant to an extent. But in light of the above-mentioned effects of burns on lumbricid worm abundance, poor foraging opportunity for snakes well may be a major factor.

Wilgers and Horne (2006) noted that "four small-bodied earthworm-eating snakes (*D. punctatus*, *S. dekayi*, *T. lineatum*, and *C. vermis*) were found in much lower abundances than expected in the two higher-burn frequencies [intermediate and annual] . . ."; in particular, they found that *Diadophis punctatus* "significantly preferred long-term unburned habitat . . ." and ascribed this tendency to higher soil moisture and greater earthworm availability in unburned habitat. *Storeria dekayi* is far more resistant to desiccation than *D. punctatus* (Elick and Sealander 1972; Cervone 1983), suggesting that the role of soil moisture in affecting worm abundance at the soil surface, coupled with more thatch for worm food and snake concealment in less frequently burned tracts, are more important to these two surface-feeding snake species than soil moisture alone acting directly upon snakes. *Virginia valeriae* is equivalent to *S. dekayi* in desiccation resistance (Elick and Sealander 1972). *Carphophis vermis* is an adept burrower, readily able to seek prey beneath the surface, though such foraging in burned tracts would reduce its visibility to investigators.

Land use practices such as haying and mowing have impacts similar to those of burning. Regular haying removes almost as much organic matter as burning, and can lead to lower lumbricid worm production and/or shifts in species composition towards smaller worm species (Lofs-Holman 1983). Kjoss and Litvaitis (2001) found *Storeria dekayi* and *S. occipitamaculata* entirely lacking in regularly mowed sites, and speculated that frequent mowing reduced diversity of vegetation, which in turn reduced ground-level moisture and thus prey for these two species. Interpretation of their results was complicated by the fact that their frequently mowed, small-patch sampling stations also were close to roads. A negative association between habitat proximity to roads (also buildings) and abundance of *Virginia valeriae* was also noted by Fitzgerald and Nilon (1993) in Wyandotte County, Kansas. However, an unpublished study of *V. valeriae* at Miami County (Kansas) State Lake (Kessler, 2009 pers. comm.) found this species regularly between 1997–2004 at a site close to an access road and camping area. The species also has been collected crossing paved

roads in various parts of its range (see for example Durso et al., 2009).

Considering the published evidence relating the removal of thatch by frequent haying (or similar effects of mowing), and consequent effects upon surface moisture and earthworm abundance, these apparently negative habitat associations between roads and small, mainly vermivorous snakes probably more reflect nearby vegetation management practices than the mere presence of a road. None of the studies cited make mention of traffic density along said roads, or potential toxins applied for insect or vegetation control that may affect snakes and/or earthworms.

Application of chemicals has been shown to have a profound effect upon the abundance of snakes like *Thamnophis sirtalis*, *Ophedryx vernalis*, and *Storeria o. occipitamaculata* (Campbell and Campbell 2001). The ecotoxicology of reptiles in urban habitats is a relatively new field of study (see Section III, Chemical and Light Pollution in Mitchell et al., 2008) that holds promise for understanding the effects of urban chemicals on snakes relying upon diets of worms, slugs and insects. These environmental variables are worthy of further study to better define the influence of encroaching urbanization on populations of relatively uncommon prey-specialist snake species.

Small, semi-fossorial snakes lacking the vagility of genera such as *Coluber* and *Thamnophis* are increasingly threatened by habitat fragmentation and alterations caused by human land use practices that extirpate local snake populations. These may be as extensive as clearing habitat for a housing or shopping development, certain timber harvesting practices (Todd and Andrews 2008), or (as alluded to above) on a much smaller scale using heavy equipment to remove fence lines or wooded edge habitat for grassland restoration projects. This greatly complicates the dynamics of conservation of these snake species, since islands of habitat created anthropogenically for mitigation may in fact be useless if resident populations of genera such as *Storeria*, *Virginia*, *Carphophis*, etc. have been extirpated from said islands (or have had populations reduced to levels constituting genetic catastrophe). These effects are by no means well understood; interestingly, urbanization can in some circumstances enhance population viability of certain small snakes (Gaul 2008).

Site fidelity and habitat conditioning, both of which influence the time required for a particular site to be used regularly by snakes (cf. Dundee and Miller 1968), are complicating variables that deserve greater research attention. Parmelee and Fitch (1995) commented "Over 40 years of checking artificial shelters in northeast Kansas by HSF has shown that snakes are rarely recaptured under the same shelter on successive visits. . . . in general, individual snakes have activity ranges of several hectares and do not return to any one spot consistently." However, more recently Fitch (1999: 148) noted that "For each species certain shelters seem to be preferred and were known to have been used several or many times, whereas other shelters that appeared to be equally suitable were used only once or not at all." My recapture data support the latter. In addition to the four species that are the main focus of this study, 7 of 18 *Coluber constrictor* records in 2007 occurred at two well-separated shelters of the 11 where this species was observed.

The information from this study, combined with data from earthworm ecology studies and research on snake populations in different land use regimes, begins to point to a successful plan for habitat management to avoid damage to resident populations of secretive and relatively uncommon vermivorous snake species.

All collection methodologies contain some element of bias, and as most recently pointed out by Heatwole and Stuart (2008) "Rarity" and "commonness" is more of a perception than a reality for some species." Though my study protocol has successfully revealed much about the ecology of Kansas *Virginia valeriae*, it would be remiss to describe these animals as common. *V. valeriae* in Kansas presently is patchily distributed with low population densities, though causes of this fragmentation remain speculative. This distribution, coupled with low vagility and specialized diet, make the species vulnerable to the increasing urbanization of northeastern Kansas as a function of both habitat destruction and potential contamination of the earthworm resource by the seemingly inevitable chemical effluent of suburbia.

**Acknowledgments:** For direct help in the field and/or for helpful suggestions, thanks are expressed to (alphabetically) Brett Benz, Michelle Bond, Joey Brown, William Busby, Scott Campbell, Donald Clark, the late Henry S. Fitch, Erin Flynn, Bruce Johanning, Ethan and Heather Lynds, W. Dean Kettle, Galen Pittman, Mark and Stephen Robbins, Stan Roth, and Travis W. Taggart.

W. Dean Kettle and William Busby provided valuable land use history data on the tract and surrounding areas. GIS modeling was done by Jorgina Ross (KBS).

For access to Kansas Biological Survey and Ecological Reserves (KBS/KSR) land, and for use of facilities, I thank Ed Martinko (Director) and Jerry Denoyelles (Assistant Director) of KBS. Rick Kooser, and Bill and Carolbeth Crahan granted access to private property adjacent to KBS/KSR tracts. R. W. McColl and family graciously donated major funding toward purchase of the site as part of the Suzanne Ecke McColl Nature Reserve (now part of KBS/KSR lands).

Continuous primary funding from Kansas Department of Wildlife and Parks Chickadee Checkoff (KDWP Non-Game Program, Ken Brunson, Coordinator) is gratefully acknowledged, as is support from a State Wildlife Grant to Travis W. Taggart, Sternberg Museum of Natural History, Fort Hays State University, from KDWP and the US Fish & Wildlife Service. Additional funding, directly or indirectly, from the Kansas Biological Survey and Kansas Herpetological Society also is most gratefully acknowledged.

Earlier drafts greatly benefited from review by William Busby, W. Dean Kettle, Barbara Paschke, and Stan Roth. Additionally I am grateful to Joseph T. Collins and Travis Taggart for help with illustrations and formatting.

Special thanks are extended to Norman Slade for his considerable investment of time analyzing the large and complex sets of temperature and humidity data, and to my late friend and colleague, Henry Fitch, for his years of insight and mentoring.

## Literature Cited

- Ahrens, J. 1997. Amphibian and reptile distributions in urban riparian areas. Master's Thesis, Univ. Missouri, Columbia. Pp. viii + 70
- Bradford, J. 1973. Reproduction and ecology of two species of Earth Snakes: *Virginia striatula* and *Virginia valeriae*. Doctoral Thesis, Univ. Missouri, Columbia.
- Campbell, K. R. and T. S. Campbell. 2001. The Accumulation and Effects of Environmental Contaminants on Snakes: A Review. *Environmental Monitoring and Assessment* 70: 253–301.
- Cervone, T. H. 1983. The natural history of *Virginia valeriae pulchra* (Serpentes:Colubridae). Unpubl. Doctoral Thesis, St. Bonaventure Univ., New York. 183 pp.
- Christiansen, J. L. 1973. The distribution and variation of the Western Earth Snake, *Virginia valeriae elegans* (Kennicott) in Iowa. *Proc. Iowa Acad. Sci.* 80: 167–170.
- Clark, D. R., Jr. and R. R. Fleet 1976. The Rough Earth Snake (*Virginia striatula*): Ecology of a Texas population. *Southwest. Nat.* 20(4): 467–478.
- Clark, D. R., Jr. 1970. Ecological Study of the worm snake (*Carpophis vermis*) Kennicott. *Univ. Kansas Publ. Mus. Nat. Hist.* 19(2): 85–194.
- Collins, J. T. and S. L. Collins. 1993. Amphibians and Reptiles in Kansas, 3rd Edition. Univ. Press Kansas, Lawrence. xx + 397 pp.
- Dundee, H. A. and D. A. Rossman. 1989. The Amphibians and Reptiles of Louisiana. Louisiana St. Univ. Press, Baton Rouge. xi + 300 pp.
- Dundee, H. A. and M. C. Miller. 1968. Aggregative behavior and habitat conditioning in the Prairie Ringneck Snake, *Diadophis punctatus arnyi*. *Tulane Stud. Zool. Bot.* 15: 41–58.
- Durso, A. M., K. T. Nelson, and E. D. Osburn. 2009. *Virginia valeriae*: Geographic Distribution. *Herpetol. Rev.* 40(2): 239–240.
- Edwards, C. A. 1983. Earthworm ecology in cultivated soils. Pp 123–137 *in* *Earthworm Ecology: from Darwin to Vermiculture*. J. E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.
- Elick, G. E. and J. A. Sealander. 1972. Comparative water loss in relation to habitat selection in small colubrid snakes. *American Midl. Nat.*, 88: 429–439
- Fitch, H. S. 1999. A Kansas snake community: composition and changes over 50 years. Krieger Publishing, Malabar, Florida. xii + 165 pp.
- Fitch, H. S. 1982. Resources of a snake community in prairie-woodland habitat of northeastern Kansas. Pp. 83–97 *in* *Herpetological Communities*. Wildlife Research Report No. 13., N. J. Scott, Jr., ed. USFWS, Washington. D.C. v + 239 pp.
- Fitch, H. S. 1975. A demographic study of the Ringneck Snake (*Diadophis punctatus*) in Kansas. *Misc. Publ. Univ. Kansas Mus. Nat. Hist.* No. 62. 1–53.
- Fitch, H. S. 1970. Reproductive cycles in lizards and snakes. *Misc. Publ. Univ. Kansas Mus. Nat. Hist.* No. 52: 1–247.
- Fitch, H. S. 1965. The University of Kansas Natural History Reservation in 1965. *Misc. Publ. Univ. Kansas Mus. Nat. Hist.* No. 42: 1–60.
- Fitch, H. S. 1956. Temperature responses of free-living amphibians and reptiles of northeastern Kansas. *Univ. Kansas Publ. Mus. Nat. Hist.* 8(7): 417–476.
- Fitzgerald, E. C. 1994. Habitat Suitability Index models for three threatened snake species in an urban county. Masters Thesis, Univ. Missouri, Columbia. x + 104 pp.
- Fitzgerald, E. C. and C. H. Nilon. 1993. Testing the accuracy of an HSI model in an urban county. *Transactions of the 58th North American Wildlife and Natural Resource Conf.* 58:1 17–123.
- Gaul, Jr. R. W. 2008. Ecological observations of the Northern Brown Snake (*Storeria dekayi*) in an urban environment in North Carolina, USA. Pp. 361–363 *in* Mitchell, J. C., R. E. Jung Brown, and B. Bartholomew (editors). *Urban Herpetology*. SSAR Herpetol. Conserv. No. 3: xvii + 586 pp.
- 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* R. Siegel and N. Scott (eds). *Wildlife 2001*. Elsevier Science Publishing, Inc., London, England.
- Heatwole, H. and B. L. Stuart. 2008. High Densities of a “Rare” Skink. *Herpetol. Rev.* 39(2): 169–170.
- Henderson, P., R. Seaby, and R. Somes. 2009. *Simply Tagging Manual*. Pisces Conservation Ltd., Hampshire, UK. 97pp.
- James, S. W. and M. C. Cunningham. 1989. Feeding ecology of some earthworms in Kansas tallgrass prairie. *American Midl. Nat.* 121: 78–83.
- James, S. W. 1988. The postfire environment and earthworm populations in tallgrass prairie. *Ecology* 69(2): 476–483.
- Kjoss, V. A. and J. A. Litvaitis. 2001. Community structure of snakes in a human-dominated landscape. *Biol. Conserv.* 98: 285–292.
- Kruuk, H. and J. T. Parish. 1981. Feeding specialization of the European Badger (*Meles meles*) in Scotland. *J. Animal Ecol.* 50: 773–788.
- Lofs-Holman, A. 1983. Earthworm population dynamics in different agricultural rotations. Pp. 151–160 *In* *Earthworm Ecology: from Darwin to Vermiculture*. J. E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.
- MacDonald, D. W., 1983. Predation on earthworms by terrestrial vertebrates. Pp. 393–414 *In* *Earthworm Ecology: from Darwin to Vermiculture*. J. E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.
- Mattson, D. J., M. G. French, and S. P. French. 2002. Consumption of earthworms by Yellowstone Grizzly Bears. *Ursus* 13: 105–110.
- Mitchell, J. C., R. E. Jung Brown, and B. Bartholomew (editors). 2008. *Urban Herpetology*. SSAR Herpetol. Conserv. No. 3: xvii + 586 pp.
- Mitchell, J. C. 1994. The Reptiles of Virginia. Smithsonian Institution Press, Washington, D.C. xv + 352pp
- Parmelee, J. and H. S. Fitch. 1995. An experiment with artificial shelters for snakes: Effects of material, age, and surface preparation. *Herpetol. Nat. Hist.* 3(2): 187–191.
- Pearce, T. G. 1983. Functional morphology of lumbricid earthworms, with special reference to locomotion. *Journ. Nat. Hist.* 17: 95–111.
- Pisani, G. R. 2009. Use of an active ant nest as a hibernaculum by small snake species. *Trans. Kansas Acad. Sci.* 112(1/2): 113–118.
- Pisani, G. R. 2005. A new Kansas locality for *Virginia valeriae*. *Journ. Kansas Herpetol.* 16: 25.
- Pisani, G. R. 1971. An unusually large litter of *Virginia valeriae pulchra*. *Journ. Herpetol.* 5(3-4): 207–208.
- Pisani, G. R., and G. L. Pittman. 2009. Early activity of *Storeria dekayi* in Jefferson County, Kansas. *Journ. Kansas Herpetol.* 29: 10–11.
- Ribiero-Júnior, M. A., T. A. Gardner and T. C. S. Avila-Pires. 2008. Evaluating the effectiveness of herpetofaunal sampling techniques across a gradient of habitat change in a tropical forest landscape. *Journ. Herpetol.* 42(4): 733–749.
- Sabine, J. R. 1983. Earthworms as a source of food and drugs. Pp. 285–296 *In* *Earthworm Ecology: from Darwin to Vermiculture*. J. E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.
- Satchell, J.E. 1983. Earthworm ecology in forest soils. Pp. 161–170 *In* *Earthworm Ecology: from Darwin to Vermiculture*. J. E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.
- Setser, K. and J. F. Cavitt. 2003. Effects of burning on snakes in Kansas, USA, tallgrass prairie. *Nat. Areas Journ.* 23(4): 315–319.
- Smith, P. W. 1961. The Amphibians and Reptiles of Illinois. *Illinois Nat. Hist. Surv. Bull.* 28(1): 1–298.
- Todd, B. D. 2008. *Virginia valeriae* (Smooth Earth Snake) Threat Display. *Herpetol. Rev.* 39(4): 475.
- Todd, B. D. and K. M. Andrews. 2008. Response of a reptile guild to forest harvesting. *Conserv. Biol.* 22(3): 753–761

- Todd, B. D., J. D. Willson, C. T. Winne and J. W. Gibbons. 2008. Aspects of the ecology of the Earth Snakes (*Virginia valeriae* and *V. striatula*) in the Upper Coastal Plain. Southeast. Nat. 7(2): 349–358.
- Todd, B. D., J. D. Willson, C. T. Winne, R. D. Semlitsch and J. W. Gibbons. 2008. Ecology of the Southeastern Crowned Snake, *Tantilla coronata*. Copeia 2008(2): 388–394.
- Wilgers, D. J. and E. A. Horne. 2006. Effects of different burn regimes on tallgrass prairie herpetofaunal species diversity and community composition in the Flint Hills, Kansas. Journ. Herpetol. 40(1): 73–83.
- Wroot, A. J. 1985. A quantitative method for estimating the amount of earthworm (*Lumbricus terrestris*) in animal diets. Oikos 44: 239–242.
- Zicsi, A. 1983. Earthworm ecology in deciduous forests in central and southeast Europe. Pp. 171–177 *In* Earthworm Ecology: from Darwin to Vermiculture. J.E. Satchell, ed. Chapman and Hall, New York. xvii + 495 pp.

APPENDIX 1. Movements and Recaptures for *Storeria dekayi*, *Virginia valeriae*, *Carphophis vermis*, and *Thamnophis sirtalis* at the study site in northeastern Kansas. M = male; F = female.

*Storeria dekayi*

Sex & SVL	Dates/Stations/Distances
F 117 mm	11/13/07 at 21 Woods, 4/4/08 at 22 Woods, 20 m E
F 215 mm	3/16/07, 3/17/07 20 m N (12 > 13)
F 195 mm	3/18/07, 3/22/07 100 m SW (23–35)
F 255 mm	11/9/06, 5/16/07 20 m N (10 > 11), 5/17/07 & 5/19/07 same (#11), 5/25/07 150 m N (#18)
F 221 mm all same	5/26/07, 5/28/07 same place (#48)
F 250 mm	6/9/07, 6/10/07 (#40), 7/1/07 & 7/6/07 60 m NE (#2)
F 216 mm all same	6/14/07, 6/16/07, 6/29/07, 7/6/07, 7/8/07 all same (#33)
F 267 mm all same	7/11/07, 7/12/07 same (#22)
F 253 mm	4/4/07, 4/9/07 20 m E (#3 > 2)

Same Station = 3 of 9 Mean = 55 m (20–110), *n* = 6

Sex & SVL	Dates/Stations/Distances
M 215 mm	3/17/07, 3/27/07 same (13), 4/17/07 50 m SE (33)
M 210 mm all same	3/17/07, 3/18/07 same (8a)
M 193 mm	3/18/07, 3/21/07 20 m E (13 > 8a)
M 163 mm all same	3/11/07, 3/12/07 same (#54)
M 190 mm	3/10/07, 4/17/07 125 m NW (54 > 33)
M 210 mm all same	3/11/07, 3/12/07 same (#54)
M 250 mm	10/30/07 (21 Woods), 4/9/08 #25 (25 m SW)
M 211 mm all same	10/26/07, 11/8/07, 11/13/07, 3/25/08 same (all #22 Woods)
M 168 mm	11/13/07, 3/20/08 same (#22 woods), 3/25/08, 3/28/08 #21 Woods 20 m W
M 235 mm	3/28/08, 4/9/08 20 m S (25 > 26)

Same Station = 4 of 10 Mean = 48 m (20–125), *n* = 6

*Virginia valeriae*

Sex & SVL	Dates/Stations/Distances
F 305 mm	10/21/08–10/28/08 20 m E (27th) then same (#22 on 28th)
F 140 mm all same	3/25/08–3/28/08 same (#20) 4/9/08 20 m E
F 265 mm all same	11/8/07, 11/10/07 same place (#21)
F 105 mm all same	9/29/07–10/1/07 same (#11)
F 295 mm	4/3/07, 5/5/07 60 m S (#25-8), 5/8/07 same (#8)
F 236 mm all same	3/10/07, 3/11/07, 5/3/07 same (#10)
F 315 mm all same	3/14/07–4/19/07 14 at same place (#15)
F 320 mm	3/29/07–4/1/07 20 m W (#28-8)
F 150 mm all same	3/29/07, 4/3/07 same (#48)

Same Station = 6 of 9 Mean = 30 m, *n* = 4

Sex & SVL	Dates/Stations/Distances
M 215 mm all same	7/2/08–7/3/08 same place
M 220 mm all same	4/28/07–5/22/07 same #33
M 212 mm	3/10/07, 3/25/07 65 m SE (#22 > 2) then same 3/26/07, 3/29/07 (#2), 4/3/07 100 m W (#7)
M 205 mm 8 at same	3/13/07, 3/14/07, 3/16/07, 3/18/07, 3/19/07, 3/22/07, 3/23/07, 3/25/07 same (#22)

M 228 mm all same 3/17/07–4/2/07 7 at same (#22)  
 M 218 mm all same 10/21/07, 10/27/07, 10/28/07 same (#22)  
 M 203 mm 3/16/07, 3/21/07 45 m S (#8a > 33), 3/23/07 same (#33)  
 Same Station = 5 of 7 Mean = 70 m,  $n = 3$

*Carphophis vermis*

Sex & SVL Dates/Stations/Distances  
 F 332 mm 12 captures at 10 Woods, 3/9–23/07 & 4/9/08 13 Edge (60 m N), 4/17/08 #7 moved 40 m E  
 F 305 mm all same 3/24–27/07, 3/29/07 all at #28  
 F 310 mm all same 3/23/07, 5/26/07 both at 24 Edge  
 F 285 mm all same 5/17/07, 5/28–29/07, 6/2/07, 6/29/07 all at 22 Edge  
 F 312 mm all same 6/16/07, 7/15/07 at #60  
 F 182 mm all same 3/26–27/07 same #52  
 F 325 mm all same 5/25/07, 10/18/07 same #44  
 F 328 mm 3/26–27/07 #11 Edge, 4/19/07, 4/24/07, 4/28/07 and 5/8/07 #8 (45 m NE)  
 F 287 mm all same 5/3–5/5/07, 5/8/07 all at #25  
 F 300 mm all same 4/17/07, 4/24/07, 4/28–29/07 at same #47  
 F 285 mm 4/24/07 (#57), 4/29/07, 5/3/07, 5/22/07 (#58) 20 m SW  
 F 305 mm (started 290) 5/8/07, 5/16/07, 5/1/08 (22 Edge) 9/7/08 22 Woods (10 m N)  
 Same Station = 8 of 12 Mean 25 m ( $n = 4$ ); furthest female 45 m

Sex & SVL Dates/Stations/Distances  
 M 200 mm 4/17/07 (21 Woods), 5/18/07, 5/25/07 (21 Edge) 10 m S  
 M 267 mm 4/24/07 at #8a, 5/8/08, 5/12/08 #20 Edge 90 m N  
 M 170 mm all same 4/28–29/07, 5/3–5/07, 5/8/07 all same (#24 Edge)  
 M 243 mm all same 5/4–5/07 and 7/1/07 all same #20 Edge  
 Same Station = 2 of 4 Furthest male 90 m (4/24/07–5/8/08) Least = 10 m in 30 days mean = 50 m  $n = 2$

*Thamnophis sirtalis*

Sex & SVL Dates/Stations/Distances  
 F 785 mm probably newly emerged 3/24/07, 5/16/07 ca 180 m SE (16 Woods > 37)  
 F 465 mm 9/29/07, 10/18/07 ca 100 m N (58 > 41)  
 F 475 mm (2007) gravid 555 mm (2008) several 2007, one 2008, all at #s 12–13, mostly Edge (just 1 Woods)  
 F 555 mm 9/2/07, 4/4/08 40 m E (21 > 19)  
 F 485 mm 5/22/07, 5/29/07 20 m W (19 Edge > 18 Edge)  
 F 560 mm 5/17/07, 9/2/07 20 m E (19 Woods > 18 Woods)  
 F 570 mm 10/1/07, 10/11/07 60 m E (#7 > 40), 4/28/08 at 22 Edge possible emergent  
 F 430 mm 4/17/07, 6/5/07 ca 80 m N (8a > 19 Edge)  
 F 575 mm (gravid in June) 6/9/07, 4/28/08 180 m SW (#2 > #9)  
 F 473 mm 3/26/07, 5/19/07 180 m NE (#11 Edge > 18 Edge)  
 F 675 mm 4/17/08, 9/19/08 ca 100 m NW (#41 > 18 Edge) Grass to Edge  
 F 550 mm 9/19/08, 10/21/08, 10/28/08 (2008) back-forth 20 m on N Edge (18 Edge <> 17 Woods)  
 F 620 mm 7/3/08, 7/29/08 20 m N (15 > 16 Edge)  
 F 595 mm 9/19/08, 10/21/08 (2008) 120 m E (#23 > 17 Edge)  
 Same Station = 0 of 14

Sex & SVL Dates/Stations/Distances  
 M 430 mm all same 4/17/07, 5/17/07 same shelter (#19 Edge)  
 M 495 mm 6/5/07, 10/28/08 ca 80 m W (22 Woods > 18 Edge)  
 M 445 mm 9/2/07, 4/28/08 90 m S (#21 > 28) probably hibernated on N Edge  
 M 420 mm 10/16/07, 10/30/07 120 m SW Grass to Edge (#37 > 9)  
 M 285 mm 10/26/07, 10/28/07 60 m NE Grass to Edge (25 > 22); 5/1/08 45 m NW in at 21 Woods B  
 M 472 mm 3/25/08, 4/4/08 65 m NW (#6 > 19 Edge) Grass to Edge with female  
 M 430 mm all same 5/8/08, 5/18/08 same place  
 Same Station = 2 of 7