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NOTES ON THE SPATIAL ECOLOGY AND HABITAT USE OF THREE SYMPATRIC *NERODIA* (SERPENTES: COLUBRIDAE)

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ABSTRACT: The spatial ecology and habitat use of three sympatric water snakes (Colubridae: *Nerodia*) were studied in a large, man-made reservoir, in central Texas, USA. *Nerodia harteri paucimaculata* appeared to be more sedentary and specialized in its habitat requirements than *N. erythrogaster transversa* or *N. rhombifer rhombifer*, and the only long movements undertaken were due to habitat loss (five snakes moved 0.8 km). *Nerodia r. rhombifer* were the most vagile; one individual moved 5.8 km over 12 days, while the longest recorded movement for a *N. e. transversa* was 0.97 km over an 11 month recapture interval. There was no overall significant difference in the mean distance moved per day: *Nerodia r. rhombifer* moved 86.21 m, *N. e. transversa* moved 64.35 m/day, while *N. h. paucimaculata* moved 30.9 m/day. Preliminary data (habitat, body size and unpublished dietary differences) hint at resource partitioning, which may be a carry over from the river system in which they are thought to have evolved.

Key words: *Nerodia*, water snakes, spatial ecology, habitat use, reservoir.

Introduction

The spatial ecology of any species may be influenced by prey availability, habitat characteristics (including thermal requirements), season and/or distribution of mates, predators, and the presence of potential competitors (Diamond, 1975; Gilpin and Diamond, 1984; Gregory et al., 1987; Reinert, 1993). The causative factors behind such spatial relationships may be elusive, but the observed relationships may represent important baseline data, providing a platform for further investigation.

The last decade has seen a surge in snake ecology such that data on snake spatial ecology has increased dramatically, particularly with the refinement of radio transmitter design (Reinert, 1992). However, fundamental data on movements and spatial ecology are still lacking for many species. Whiting et al. (1996, 1997) recently reported on the activity cycles and spatial ecology of the Concho water snake (*Nerodia harteri paucimaculata*) in a large lake system. This study extends that previous work, and provides comparison with two sympatric congeners, the blotched water snake (*Nerodia erythrogaster transversa*) and the diamondback water snake (*Nerodiarhombifer rhombifer*).

Nerodia h. paucimaculata is a relatively small natricine (males mature at SVL=380 mm, females at SVL=460 mm) confined to the Concho-Colorado river drainage of Texas and its tributaries (Scott et al., 1989). Riverine habitat suitable for *N. h. paucimaculata* typically consists of numerous riffles (Rose, 1989; Scott et al., 1989). *Nerodia h. paucimaculata* are federally listed as threatened (Stefferud, 1986), and are considered endangered by the state of Texas. They have been the object of intense field study (e.g., Mueller, 1990; Greene, 1993; Whiting, 1993; Greene et al., 1994; Whiting et al., 1996, 1997), which has resulted in a conservation plan (U.S. Fish and Wildlife Service, 1993) and monitoring program to help ensure their future existence. *Nerodia e. transversa* and *N. r. rhombifer* are larger

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water snakes with broad distributions (Conant and Collins, 1991) that occur in a variety of aquatic habitats.

Nerodia h. paucimaculata's protected status was conferred largely because of its limited distribution and the concurrent threat of habitat degradation and destruction (U.S. Fish and Wildlife Service, 1993). Construction of reservoirs has resulted in habitat loss in the form of decreased stream flows, sedimentation, and vegetation encroachment (Scott et al., 1989). Although populations may persist in degraded habitat (*pers. obs.*), densities are greatly reduced and the threat of localized extirpation increased. With the impending construction of Ivie Reservoir, and the inundation of about 18% (Scott et al., 1989) and possible degradation of a further 8% of *N. h. paucimaculata* habitat, baseline ecological data on lake populations became imperative.

Here, we present data on the spatial distribution of three sympatric *Nerodia*, in a large lake system, including data on movements and body sizes (SVL).

Materials and Methods

Field work was conducted during 1990–1992 at E.V. Spence Reservoir (hereafter referred to as Spence), Texas, USA. For a detailed description of the study area see Whiting (1993) and Whiting et al. (1996, 1997). Snakes were caught in funnel traps (commercial minnow traps) and by hand during shoreline sampling. *Nerodia. h. paucimaculata* were marked using PITs (Camper and Dixon, 1988), while *N. r. rhombifer* and *N. e. transversa* were scale clipped (Brown and Parker, 1976).

Limited data on movements (m), distribution, and habitat use for both *N. r. rhombifer* and *N. e. trensversa* were obtained, and compared to a more substantial data set for *N. h. paucimaculata*. Three types of habitat were categorized: shoreline, creeks/coves and well sites. Because sampling was geared primarily towards known populations of *N. h. paucimaculata* at Pecan Creek and Pump Station (both shoreline localities), well sites and coves/creeks were sampled less frequently. For the purpose of this paper, a well site is a man-made oil well consisting of a small hill with rock-strewn slopes. Depending on water level, well sites either occurred as islands or part of the shoreline. Coves/creeks consisted of sheltered inlets on the lake itself. Therefore, habitat use was measured using only trap data (trap nights/no. of captures), thereby negating any bias caused by differential sampling of habitat type. Also, the bias caused by hand sampling neonate snakes (all three species), which were frequently found in high aggregations within the first month of parturition, was avoided by trapping. (Neonates were generally not caught in traps until they were several months old, at which point many individuals had dispersed.) Trap placement was designed towards maximum capture of *N. h. paucimaculata*, therefore no statistical analysis was applied. However, trends in habitat use by *N. r. rhombifer* and *N. e. transversa* were sought, and compared to those obtained for *N. h. paucimaculata*.

Differences in distance moved/day (movement rate *sensu* Whiting et al., 1997) were assessed using one-way Kruskal-Wallis ANOVA (two-tailed). The relationship between body size and mean distance moved/day was evaluated using Spearman rank correlation coefficients. Differences in body length (snout-vent length, SVL; $\log_{(10)}$ transformed) among the three species was evaluated using ANOVA and post hoc pairwise Scheffé tests. Only individuals with an SVL>500 mm was used for the body size analysis because of the high number of neonate and juvenile *N. h. paucimaculata* captured. Means are reported±1SE. Differences were considered significant at alpha<0.05.

Results and Discussion

Nerodia r. rhombifer (N=9) moved a mean daily distance of 86.21±39.85 m (2–321), *N. e. transversa* (N=6) moved 64.35±25.84 m (12.8–179)/day, while *N. h. paucimaculata* (N=8 telemetered individuals; Whiting et al., 1997) moved 30.9±3.5 m (0–458.9)/day. There was no overall difference (H=0.87, P=0.65) in mean daily distance moved/day among the three species, although differences were likely masked by limited sample sizes and low recapture rates for *N. r. rhombifer* and *N. e. transversa*. Recapture interval and low

Table 1. Total number of snakes captured for all three species of *Nerodia*, by habitat, at E.V. Spence Reservoir, 1990–92. Samples include both hand captured and trapped snakes. Numbers in parentheses are individuals. Some individuals are duplicated when they were caught in more than one habitat type.

Habitat type	*N. e. transversa*	*N. r. rhombifer*	*N. h. paucimaculata*
shoreline	18(17)	100(51)	646(236)
creeks/coves	21(18)	45(41)	62(37)
well sites	37(28)	108(72)	48(26)

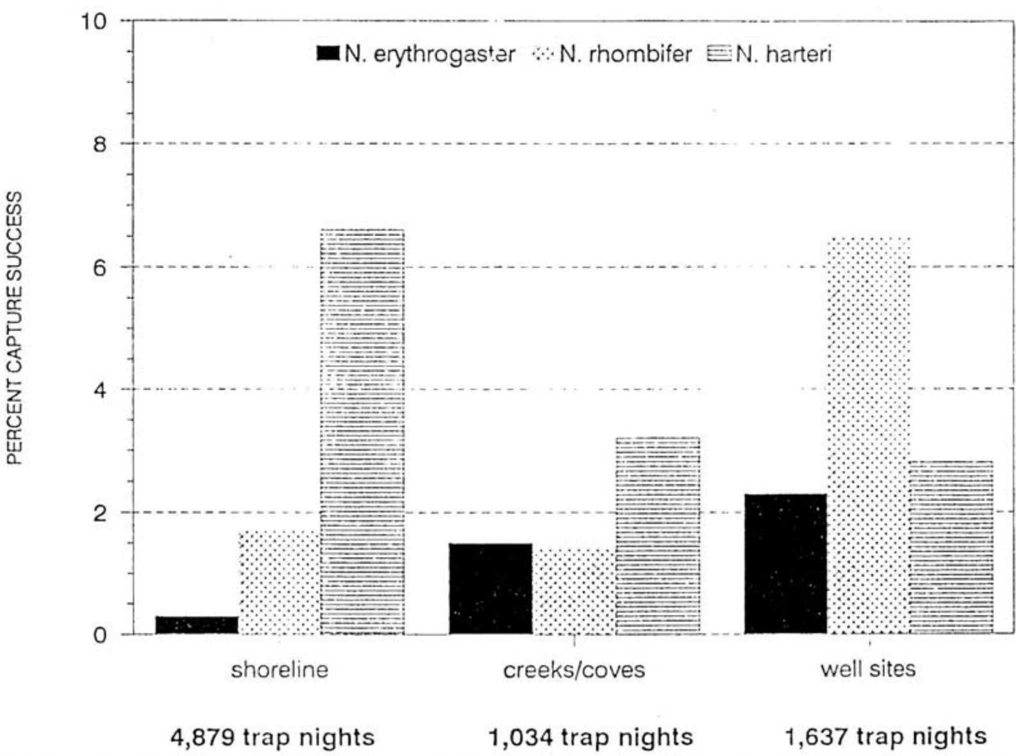

Fig. 1. Trapping success of *N. e. transversa*, *N. h. paucimaculata*, and *N. r. rhombifer* by habitat, at E. V. Spence Reservoir, for 1990–92.

sample sizes for *N. r. rhombifer* and *N. e. transversa* has likely negatively biased the mean distance moved/day. There was also no relationship between body size and distance moved/day (*N. r. rhombifer*: $r_s=-0.47$, $P>0.2$; *N. e. transversa*: $r_s=-0.66$, $P=0.2$; *N. h. paucimaculata*: $r_s=0.13$, $P>0.5$; all three taxa combined: $r_s=-0.3$, $P>0.1$). Again, limited sample sizes may have obscured any real relationship. However, other confounding factors such as sex, reproductive condition, and stochastic factors (changes in lake elevation) may also mask any relationship between body size and movement rate.

Of the three species of *Nerodia*, *N. r. rhombifer* was the most vagile. The longest recorded emigrational movement was 5.8 km, over a 12-day period, made by a male *N. r. rhombifer*. This compared to 0.97 km for an adult female *N. e. transversa* over an 11-mo recapture interval, and 0.8 km for five adult *N. h. paucimaculata* of both sexes over periods of a few days. *Nerodia r.*

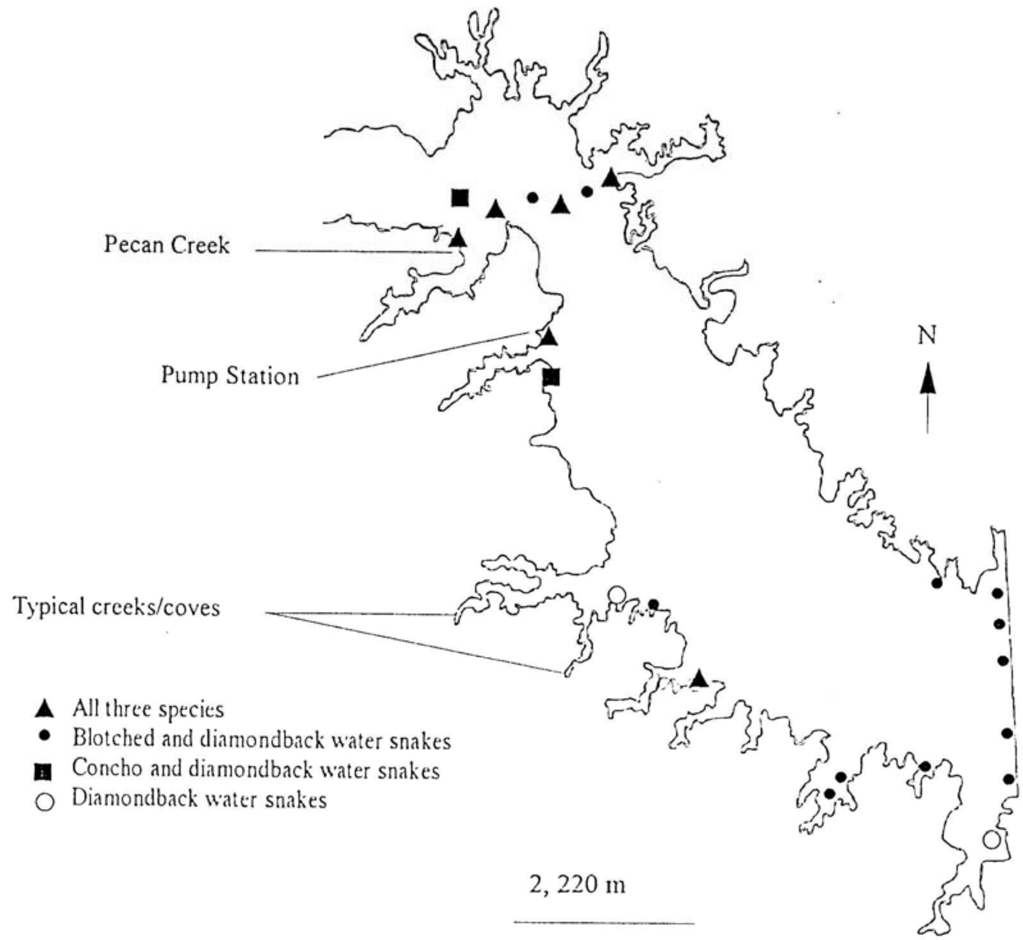

Fig. 2. The distribution of *N. e. transversa*, *N. h. paucimaculata*, and *N. r. rhombifer* at E. V. Spence Reservoir, for 1990–92. Islands in the northern reaches of the lake are well sites.

rhombifer frequently moved between disjunct habitats (continuous rock separated by at least 100 m). Seven *N. r. rhombifer* moved between three or more habitats, while five moved between at least two sites, based on trap records. The low recapture rate for *N. r. rhombifer* (Table 1) also suggested high vagility. Spence is a dynamic system with constantly fluctuating water levels which in turn affects habitat availability (Whiting et al., 1997). Loss of habitat was the likely cause of the five *N. h. paucimaculata* moving 0.8 km each.

Nerodia h. paucimaculata preferred shoreline habitat to that of coves/creeks and well sites; *N. r. rhombifer* and *N. e. transversa* preferred well sites; although, for *N. e. transversa* this could change with larger sample sizes (Table 1; Fig. 1). All three species were frequently found syntopically (Fig. 2), although relative abundance depended on habitat type (Table 1). *Nerodia h. paucimaculata* appeared to have the narrowest habitat requirements, resulting in a localized distribution within the lake basin. The majority of *N. h. paucimaculata* were clustered at two sites, Pecan Creek and Pump Station; most *N. r. rhombifer* were caught at well sites, while *N. e. transversa* were fairly evenly distributed among sites containing snakes (Fig. 2).

Snake communities have been shown to partition resources (Mushinsky and Hebrard, 1977; Vitt and Vangilder, 1983). In an artificial system only 25-years old, one would be hard pressed to ascribe resource partitioning. Possible partitioning that may have occurred in the Colorado River prior

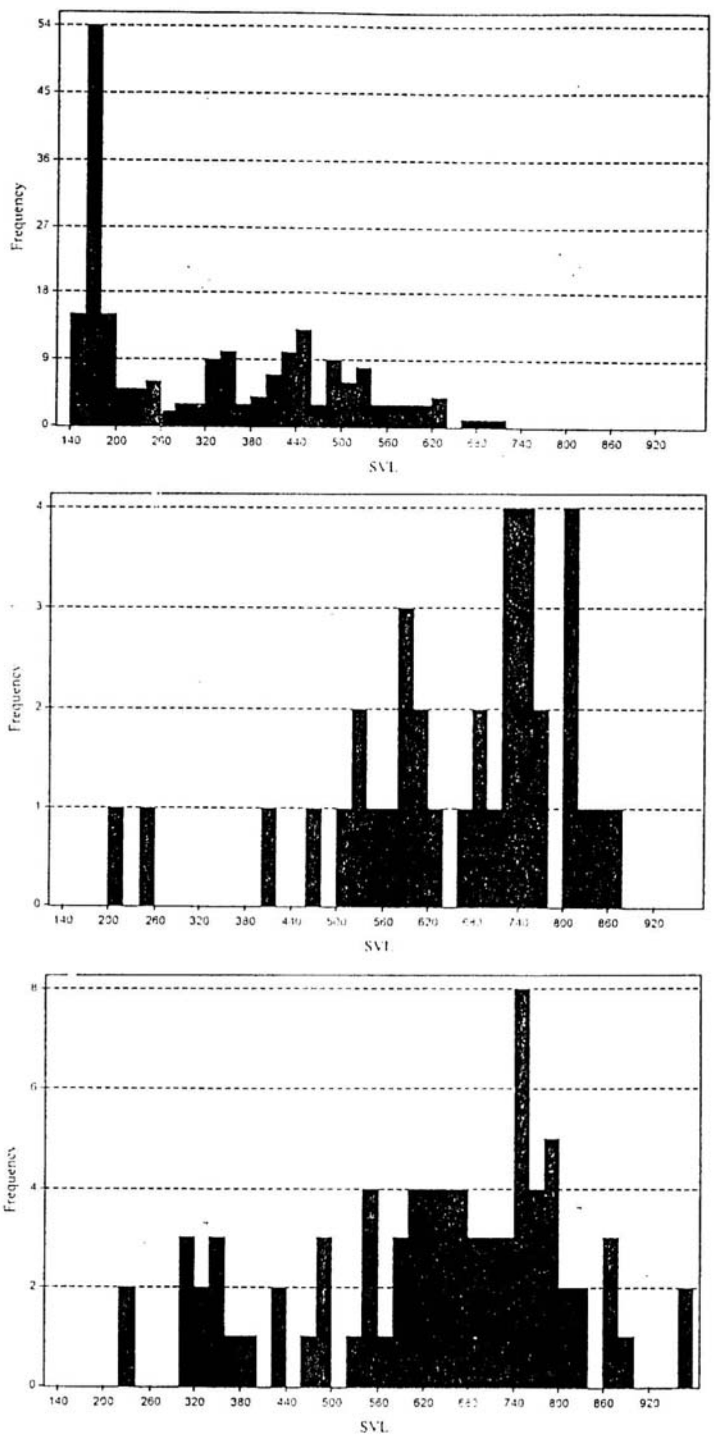

Fig. 3. Distribution of body sizes (SLV; mm) for *Nerodia* caught at E. V. Spence Reservoir during 1990–92: (a) *N. h. paucimaculata*, (b) *N. e. transversa*, (c) *N. r. rhombifer*.

to impoundment has perhaps been carried over to the reservoir system. The present sample sizes, as well as the nature of the data collected, precluded an analysis of resource partitioning among the three species. However, the present study indicates differences in habitat preference among the three *Nerodia*, although differences between *N. erythrogaster* and *N. rhombifer* were not great. There were also differences in body size (Fig. 1). An analysis of SVL for all individuals over 500 mm for 1990-92 revealed a significant difference (ANOVA, $F_{2,175}$=42.01, P<0.0001); *N. h. paucimaculata* ($\bar{x}$=562.44±7.59, range: 500–695, N=47) was significantly (Scheffé test, P<0.05) smaller than both *N. erythrogaster* ($\bar{x}$=706.85±14.37, range: 524–930, N=44) and *N. rhombifer* ($\bar{x}$=704.65±12.75, range: 505–1186, N=87), which were not significantly different from one other (P>0.5). Therefore, preliminary evidence suggests some resource partitioning by the three species of *Nerodia*, albeit due to differences in physiological requirements. Also, dietary data collected for river populations of all three species of *Nerodia* show differences in prey utilization (BDG, *unpublished data*).

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要　　約

アメリカミズヘビ３種の空間と環境の利用

M. J. Whiting*, J. R. Dixon and B. D. Greene**

テキサス中部の人工湖で，アメリカミズヘビ属（*Nerodia*）の空間と環境の利用について研究を行った．*N. harteri paucimaculata* は，他の２種より固着性で，特定の環境に特殊化しており，その環境が失われたときだけ長い移動を行った．*N. r. rhombifer* は，最も移動性に富み，ある個体は12日で5.8 km 移動した．一方，*N. erythrogaster transversa* は，11ヶ月で0.97 km しか動いていない．１日の平均移動距離には有意な差はなかった．それらの生息環境，体の大きさ，食性などの予備的な調査データから，それらが進化してきた河川系列から持ち越されてきた，資源の分割の仕方が示唆された．

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