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Life history traits in the northern ring-necked snake, *Diadophis punctatus edwardsii* (Merrem, 1820), in West Virginia

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ABSTRACT - To describe the life history traits of the northern ring-necked snake (*Diadophis punctatus edwardsii*), we examined 187 museum specimens collected in West Virginia during 1926–2000. This facilitated geographical comparisons across the species range and will serve as a baseline to detect future changes in life history traits that could result from climate change. Our findings revealed a unimodal distribution of captures during January–October. Such a distribution could arise from unequal sampling effort, nevertheless such a distribution is typical of those species in the mid-Atlantic and north-eastern region of the United States. The male gonadal cycle conformed to the temperate pattern, whereas that of females tended towards a tropical pattern. Females oviposit during April–July, which began earlier than those of surrounding northern states; however, the June peak in captures of gravid females was similar to that found elsewhere in its geographic range. Mean clutch size (4.3 eggs) was similar to those reported from elsewhere in the eastern USA, and mean adult body size of males (26.4 cm SVL) and females (28.9 cm SVL) typified those of northern populations. Age at sexual maturity was similar to that of conspecifics from Pennsylvania. For many females, first clutches occurred at an older age than those in Florida. Our findings corroborated the relative stability of some life history traits as well as geographic variation in other traits. These may be subject to change in response to contemporary and future region-wide changes in climate.

INTRODUCTION

Twenty-two species of snakes are native to West Virginia, in the USA (Green & Pauley, 1987). The northern ring-necked snake, *Diadophis punctatus edwardsii* (Merrem, 1820), is geographically widespread in West Virginia. Despite the ubiquity of this species, little attention has been paid to its ecology in the state. Access to West Virginia specimens from the holdings of the Carnegie Museum of Natural History and the herpetological collection of Marshall University provided us with the opportunity to examine certain life history traits of the northern ring-necked snake. We recognise that the opportunistic nature of this collection limits assessment of seasonal activity patterns in West Virginia but it enabled us to document seasonal activity and reproduction for comparison with data from other latitudes and to discuss the role of these data as a baseline for future comparisons in relation to climate change.

MATERIALS AND METHODS

We examined specimens that were captured during 1926–2000 and deposited in Marshall University Museum of Natural History and the Carnegie Museum of Natural History. We recognise that the opportunistic nature of this collection limits assessment of seasonal activity patterns in West Virginia. Body length of each specimen was measured in cm snout-vent length (SVL). Sex was determined by internal examination of the gonads through dissection. Enlarged testes indicated sexual maturity in males. The length and width were measured and recorded in mm. These measurements were equated into a percentage of the SVL. This percentage was then used as an indicator of fertility and plotted by month on graphs. Methods by Trauth et al. (1994) served as guidelines for size ranges associated with categories of ovarian follicles and oviductal eggs and embryos. Follicles < 2 mm were deemed immature. Vitellogenic ovarian follicles were generally ≥ 3 mm.

The largest ovarian follicle among those follicles ≥ 2.0 mm, yellow in colour, were recognised as vitellogenic and used to provide a measure of monthly follicular growth. The largest oviductal eggs or embryos were measured for a monthly estimate of respective growth rates. Clutch size was estimated by counts of enlarged follicles, oviductal eggs or counts of young. Mean values were followed by + 1 standard deviation. F-tests were performed to test for statistical differences in variances around the means. Two-tailed t-tests were used to assess statistical differences between means, and regressions were calculated to quantify relationships in reproductive characteristics. Statistical analyses were undertaken in Excel, and statistical significance was recognised at $p<0.05$.

RESULTS

We examined 187 specimens of the northern ring-necked snake from collections made during 1926–2000 in West

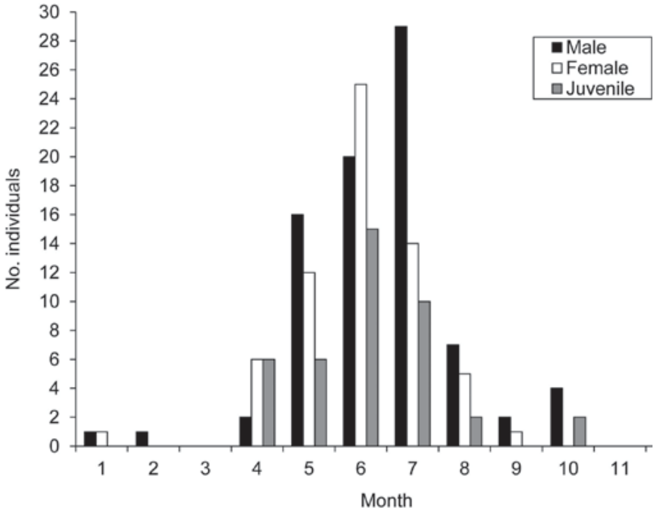

Figure 1. Monthly incidence of capture of 82 male, 64 female and 41 juvenile northen ring-necked snaked (*D. punctatus edwardsii*) from West Virginia

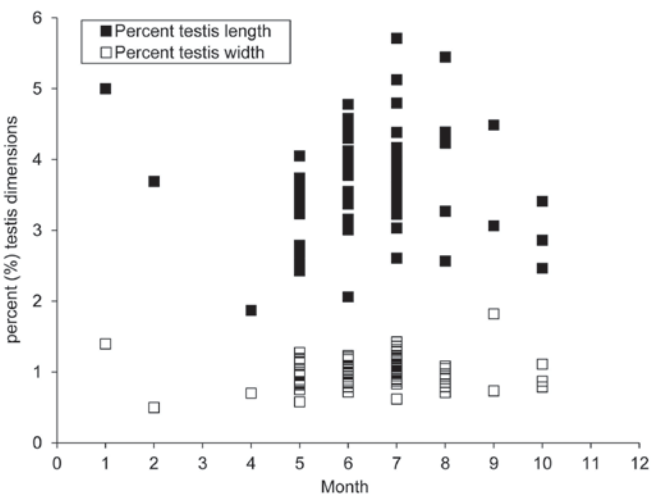

Figure 2. Monthly distribution of testis size as a percentage of male snout-vent length (SVL) of 71 northern ring-necked snakes (D. *punctatus edwardsii*) from West Virginia

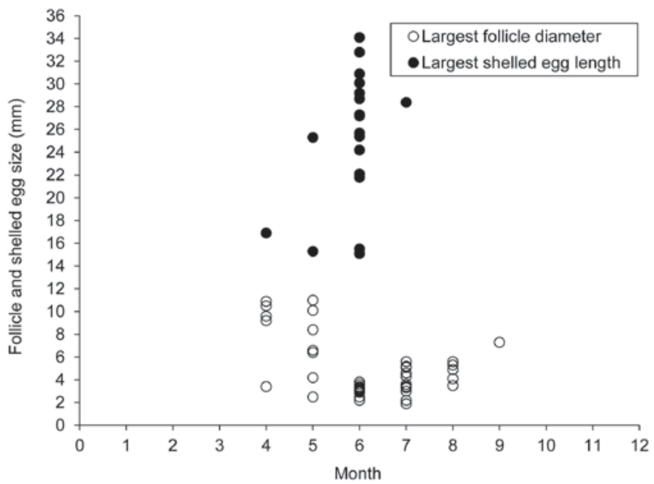

Figure 3. Monthly distribution of follicle (n = 40) and ovum size (n = 19) in 59 northern ring-necked snakes (D. *punctatus edwardsii*) from West Virginia

Virginia. Individuals were collected during January–October (Fig. 1). As determined by incidence of capture, a unimodal pattern to seasonal activity was evident in this sample and peaked in June (Fig. 1). A unimodal pattern to seasonal activity was also apparent in each sex- and size-class, with numerical peaks in June (females, juveniles, all individuals combined) and July (males) (Fig. 1).

Monthly distribution of testis size revealed a unimodal peak in both length and width in July (Fig. 2). Females bearing shelled eggs were detected during April–July (Fig. 3). Most gravid females were found in June, concomitant with the smallest ovarian follicles (2.0–3.8 mm) (Fig. 3). Thereafter, largest follicle sizes increased to 7.3 mm in September (Fig. 3).

Clutch size as estimated from counts of vitellogenic ovarian follicles (9.2–11.0 mm) averaged 5.2 young (+ 2.6; range = 3–9; n = 6). Clutch size estimated from counts of shelled eggs averaged 4.1 (+ 2.3; range = 2–10; n = 22). Neither variances (F = 1.308, p = 0.30) nor means (t = 0.984, df = 26, p = 0.33) of these two clutch size estimates differed significantly. Combining data from both counts yielded a mean clutch size estimate of 4.3 (+ 2.4; range = 2–10; n = 28). Clutch size significantly co-varied with female body size (Fig. 4). Shelled egg length ranged 12.5–32.8 mm (mean = 24.0 + 5.0; n = 37). Shelled egg width ranged 4.2–9.0 mm (mean = 6.0 + 1.3; n = 37). Largest shelled egg width, but not length, significantly co-varied with both female body size (Fig. 5) and clutch size (Fig. 6).

Mean adult body size of males (mean = 26.4 + 4.6 mm SVL; range = 15.3–36.2; n = 81) was significantly smaller (F = 0.940, p = 0.40; t = -3.252, df = 144, p = 0.001) than that of females (mean = 28.9 + 4.8 mm SVL; range = 20.5–44.5; n = 65). The male: female mean body size ratio of this sample was 0.91. Using presumed body-size cohorts from a monthly distribution of body sizes (Fig. 7), the smallest individuals (< 10.0 cm SVL) captured in the fall could have reached sexual maturity, approximately 19–20 months of age. The smallest egg-bearing female (24.3 cm SVL) could have produced her first clutch a few months before her second birthday, and all females would be primiparous by 2.5 years of age (Fig. 7).

DISCUSSION

Several life history traits of the northern ring-necked snake from West Virginia were examined within the context of patterns evident across its geographic range. In the East, seasonal activity of the ring-necked snake was shown to be unimodal, the peak of which was variable among locations. For example, the peak in seasonal activity was spring or summer in Florida (Meshaka & Layne, 2015). Peak surface activity was highest in June in Pennsylvania generally (Meshaka & Wilkerson, 2008) and in south-western Pennsylvania (Meshaka, 2010). However, in south-central Pennsylvania, the peak occurred in May (Meshaka & Delis, 2014). The incidence of capture was highest in June in our study. Although also unimodal, we leave open the possibility that the observed pattern in our study is an artifact of sampling given the limitations of uneven survey

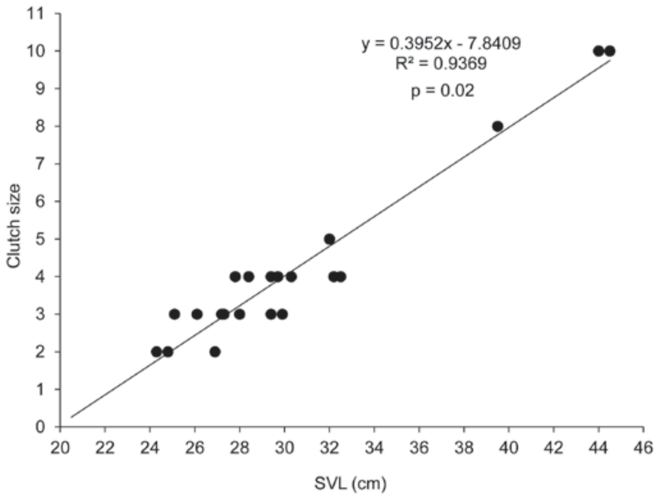

Figure 4. Relationship between clutch size and female body size of 21 northern ring-necked snakes (*D. punctatus edwardsii*) from West Virginia

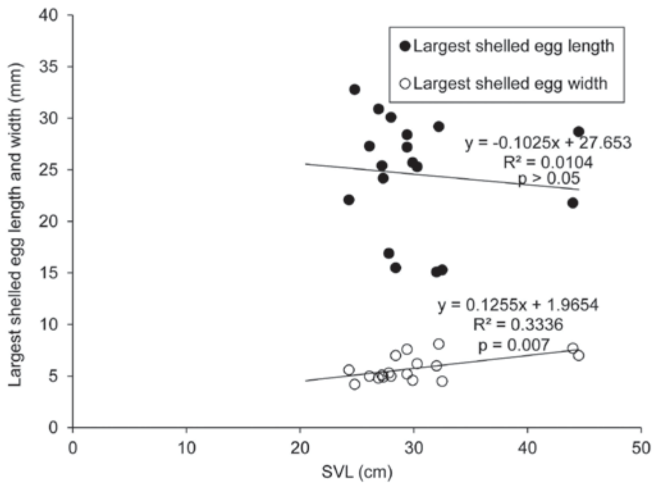

Figure 5. Relationship between largest shelled egg length and width and female body size of 19 northern ring-necked snakes (*D. punctatus edwardsii*) from West Virginia

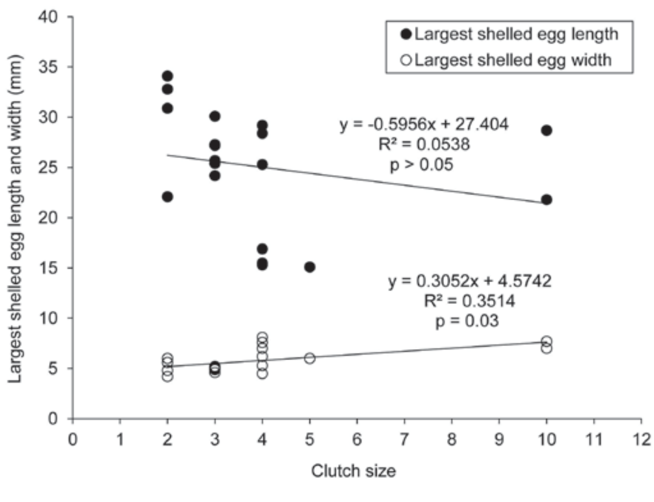

Figure 6. Relationship between largest shelled egg length and width and clutch size of 20 northern ring-necked snakes (*D. punctatus edwardsii*) from West Virginia

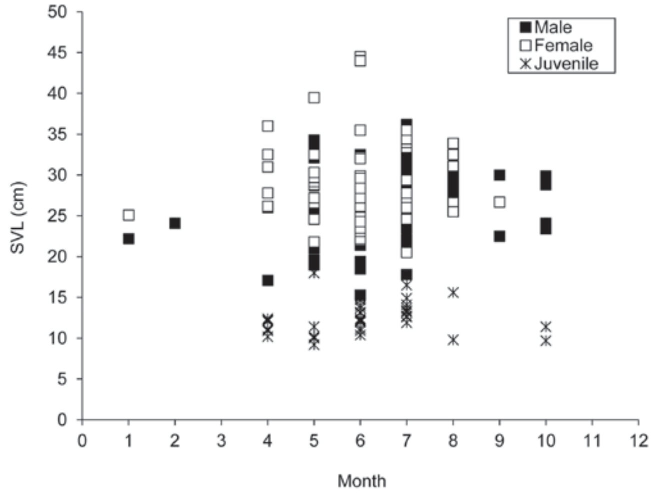

Figure 7. Monthly distribution of body size of 81 male, 65 female and 41 juvenile northern ring-necked snakes (*D. punctatus edwardsii*) from West Virginia

effort in the dataset. In Connecticut, collection success was greatest in May (Klemens, 1993). Farther west, the seasonal activity pattern of the prairie ring-necked snake (*D. p. arnyi* Kennicott, 1859) in north-eastern Kansas was bimodal, with spring and fall peaks (Fitch, 1975).

The duration of the activity season in the ring-necked snake was longer in the south than in the north (Meshaka & Layne, 2015). In southern Florida, individuals were active year-round, especially in the spring, and were typically active during April–October farther north (Meshaka & Layne, 2015). In our study, most individuals were collected during April–October, with a few found in January and February, which is similar to an active season of April–October in Pennsylvania (Meshaka and Wilkerson, 2008), May–mid-October in southern New England (Klemens, 1993), and mid-April–mid-October in New York (Wright & Wright, 1957). North-eastern Kansas populations were active during late-March–early-November (Fitch, 1975).

The male gonadal cycle of the northern ring-necked snake in West Virginia conformed to that of other north temperate populations of colubrid snakes, whereby spermatogenesis occurred in the summer (Saint Girons, 1982). The same pattern was reported in northern ring-necked snakes from New Jersey (Price, 1975) and Pennsylvania (Meshaka & Wilkerson, 2008).

On the other hand, vitellogenesis in West Virginia northern ring-necked snakes adhered to a tropical pattern to vitellogenesis (Aldridge et al., 1995) rather than the type II spring vitellogenesis pattern, typical of north temperate colubrids (Aldridge, 1979; Aldridge et al., 2009). The same pattern was evident in females from Pennsylvania (Meshaka & Wilkerson, 2008). Interestingly, Fitch (1975) described what would be interpreted as spring vitellogenesis in a north-eastern Kansas population.

The egglaying season was found to be longest in Florida (May–September) and typically to occur during June–July farther north (see Meshaka & Layne, 2015). Oviposition occurred during 16 June–21 July in Virginia (Mitchell, 1994) and during April–July in our study. In New Jersey, ovarian mass was greatest in June before ovulation, and egglaying was expected during July–August (Price, 1975). Farther north, eggs were laid during June–July in Pennsylvania (Hulse et al., 2001; Meshaka & Wilkerson, 2008) and in July in northern Michigan (Blanchard, 1942). The late-June–early-July egglaying season in north-eastern Kansas (Fitch, 1975) was similar to much of the Mid-Atlantic and North-east.

Clutch characteristics varied little with respect to clutch size. A mean of 3–4 eggs/per clutch was typical in the East (Meshaka & Wilkerson, 2008; Meshaka & Layne, 2015). Data from our study did not conflict with this trend. A mean clutch size of 3.4 eggs in north-eastern Kansas prairie ring-necked snake populations (Fitch, 1999) also conformed to this pattern. Likewise, our data did not conflict with the finding of a positive relationship between clutch size and female body size reported in Pennsylvania (Hulse et al., 2001; Meshaka & Wilkerson, 2008) and north-eastern Kansas populations (Fitch, 1975).

Mean body sizes of adult ring-necked snakes were found to be larger in northern and north-eastern Kansas populations (Meshaka & Layne, 2015). Data from our study corroborate that trend, as does the weak sexual dimorphism in body size that favoured slightly larger female body size (Meshaka & Layne, 2015). We note, however, the importance of variation in mean body size associated with habitats (Fitch, 2004).

Meshaka & Layne (2015) noted delayed maturity in northern populations of this species. Monthly body size distributions in our study were suggestive of sexual maturity in females by their second spring. If so, some females could lay their first clutch of eggs before they reach two years of age, and all females could mate in the fall just after they have passed two years of age. A similar observation was made in Pennsylvania (Meshaka & Wilkerson, 2008). First clutches in north-eastern Kansas were produced by females in their third year (Fitch, 1999), when presumably all females in our study would be ready to lay eggs for the first time.

Despite its ubiquity and ease of capture, the northern ring-necked snake remains a poorly-studied subject of ecology in the East. Our findings corroborated the relative stability of some life history traits in this species as well as geographic variation in other traits. In turn, understanding these patterns can provide a measure of predictability in the likelihoods of responses by the northern ring-necked snake in other places yet to be studied. These data are, in turn, useful in understanding factors that influence life history traits and in applied terms, for species management. The effect of climate on aspects of ophidian ecology as indicated in our findings was a matter of spatial comparisons to test life history patterns. Our dataset ended in 2000. Since that time, human-mediated changes to climate pattern have been shown to be severe and to affect ecology, geographic range, and even existence of amphibian and reptile species. For example, climate change affects phenology and population structure of amphibians (Blaustein et al., 2001 & 2010, Corn, 2005). Identified as a threat to reptiles (Gibbons et al., 2000), Aubert and Shine (2010) reveal the challenge of thermal plasticity in the face of climate change-related year-to-year variation in temperature. More broadly yet, south-east Asian amphibian and reptile species will within 50 years meet or exceed most limits in their ability to adapt to effects of climate change with respect to temperature-dependent sex determination, higher metabolic rates, and less bio-available water (Bickford et al., 2010).

We proffer that even as the spatial analysis of our study corroborates predictable effects of climate on selected life history traits, it also serves as a baseline dataset for measuring future changes in the ecology of West Virginia populations of the northern ring-necked snake in advance of quantifiably different weather patterns and overall warming of their environment.

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