ABUNDANCE AND POPULATION STRUCTURE OF EASTERN WORM SNAKES IN FOREST STANDS WITH VAROUS LEVELS OF OVERSTORY TREE RETENTION

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Abstract—In-depth analyses of a species' response to canopy retention treatments can provide insight into reasons for observed changes in abundance. The eastern worm snake (*Carphophis amoenus amoenus* Say) is common in many eastern deciduous forests, yet little is known about the ecology of the species in managed forests. We examined the relationship between silvicultural techniques, particularly shelterwood cuts with varying levels of basal area retention, and the abundance and population structure of eastern worm snakes in the Cumberland Plateau of northern Alabama. Treatments included five levels of basal area retention at 15 units (4 ha/unit): 0, 25, 50, 75 percent retention, and control (100 percent retention) with three replicates each. Drift fences and coverboards were used to sample worm snake populations in each treatment. Worm snake abundance did not vary among treatments. Sex ratios were skewed towards males on clearcut treatments. The percentage of females in gravid condition did not differ among treatments, and the percentage of the sample comprised of juveniles was consistently high and also did not vary among treatments. Male worm snakes were more massive at a given length in controls than 25 percent retention treatments. Mass to length ratio increased linearly with increasing basal area for males. Our results highlight the subtle changes that these treatments exerted on eastern worm snakes.

INTRODUCTION

The eastern worm snake (*Carphophis ameonus. amoenus* Say) is a secretive, small (< 30 cm total length), fossorial snake that is distributed from southern NY and MA south to northern AL, GA, and SC (Conant and Collins 1991). In AL the species inhabits a variety of habitats, and is a common forest floor inhabitant of mesophytic forests (Mount 1975). Although the species can reach high densities relative to other reptile species in optimal habitat (Ernst and Barbour 1989), there are few detailed ecological studies of the species, especially on the effects of canopy removal. Work by Russell and Hanlin (1999) showed that this species reaches high abundances adjacent to small isolated wetlands in the Coastal Plain of SC. In KY, the species was studied using radioisotope tags and found to have small home ranges (23 to 486 m^2) (Barbour and others 1969).

The objectives of this study were to compare the abundance, demographics, population structure, and body size of eastern worm snakes across five levels of overstory tree retention in northern AL. In doing so we tested the following four hypotheses:

$H1_o$: Relative abundance of worm snakes will not vary by canopy retention treatment
$H2_o$: Sex ratio, percentage of population comprised of gravid females and juveniles will not vary by treatment
$H3_o$: Body size distribution will not vary by treatment
$H4_o$: Ratio of mass: length will not vary by treatment

STUDY AREA

The study took place in the Cumberland Plateau region of Jackson County, which is located in northeastern AL. Study sites are upland forests dominated by oaks (*Quercus* spp.), hickories (*Carya* spp.), yellow-poplar (*Liriodendron tulipifera* L.) and sugar maple (*Acer saccharum* Marsh.). Soils are composed of gravelly and stony loams, and slopes average between 12 and 20 percent.

The study followed a randomized complete block design with three blocked replicates of five treatments involving varying levels of basal area retention of trees. Treatment categories included clearcuts, 25, 50, and 75 percent retention, and controls. The clearcuts, 25, and 50 percent retention treatments were chainsaw-felled in a commercial logging operation. In 75 percent retention treatment units, the midstory was removed by incising trees and applying the herbicide Arsenal® (active ingredient imazapyr, BASF Corp., Ludwigshafen, Germany) into the cut area to achieve a shelterwood cut. Two blocks were located on a north-facing slope at Jack Gap, and the other at Miller Mountain on a southwest-facing slope. Individual experimental units were 4-ha in size.

METHODS

Stand Density

Basal area was calculated using diameter at breast height measurements taken in three permanent measurement plots within each experimental unit (Schweitzer 2003) in each year between 2002 and 2005.

Snake Sampling

The main method used to sample worm snakes was drift fence trapping. Drift fences were 15 m in length, constructed of silt fencing, and included one 19 liter pitfall bucket at each end, and two double-sided funnel traps placed on either side of fences at the midpoint. Three drift fences were placed on each unit (nine per treatment, 45 total) adjacent to the same permanent measurement plots used to measure stand density. Drift fences were opened for a total of 900 trap nights during the following periods: August to October 2002 and March to October 2003, 2004, and 2005. A trap night was defined as one drift fence open for 24 hours. Drift fences were checked daily when opened. Artificial cover objects, or coverboards, were also used for snake sampling. Two coverboard types were deployed on treatments and sampled

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up to 3 to 4 times per week between April and July of 2003 to 2005 and up to once weekly between October and March of the same years. Ninety small coverboards (30 by 20 cm), 30 at each measurement plot, were placed within each unit and sampled a total of 46 times (62 100 boards), while 9 larger (120 by 60 cm) boards, three per measurement plot, were used per plot and sampled 73 times (9 855 boards). Each captured worm snake was measured for snout-vent length (SVL) using a Lufkin steel pocket tape, weighed to the nearest 0.1 g with Pesola spring scales, probed to determine sex, and given a dorsal scale clip. Gravidity of females was assessed based on the presence of eggs which are visible within the body cavity.

Statistical Analyses

Randomized complete block ANOVA tests were used for comparison of worm snake abundance among treatments in terms of effort-adjusted drift fence and cover board captures. The same ANOVA model was used to test for treatment effect on log-transformed mass: length ratio of male and female worm snakes to determine if treatments affected body size relationships. Mean separations were performed using Tukey's HSD test. To test for differences in sex ratio, percentage of gravid females, or percentage of juveniles among the five tree retention levels we used χ^2. Simple linear regression was utilized to test for relationships between log-transformed mass to length ratio of individual male and female worm snakes and the average basal area (2002 to 2005) at the measurement plot at which they were captured. Population structure patterns among treatments were assessed graphically using a histogram of snake sizes. Data from each of the three measurement plots within a given unit were averaged for all analyses except regression of mass: length ratio and basal area. Analyses were carried out using SPSS V. 10.0 and $P < 0.05$ for significance.

RESULTS

A total of 206 individual eastern worm snakes were captured, excluding 35 recaptures. This total included 127 snakes captured with coverboards and 79 captured with drift fences. Ninety of these were juveniles (< 165 mm SVL; Russell and Hanlin 1999) whereas 116 were classified as adults. The sample included 44 males and 56 females, 17 which were gravid.

Relative Abundance

Worm snake abundance did not differ by treatment in terms of either drift fence ($F_{4,10} = 0.37$, $P = 0.82$) or coverboard ($F_{4,10} = 2.01$, $P = 0.17$) captures (fig. 1 a, b). Because the two sampling techniques showed similar patterns of abundance among treatments, drift fence and coverboard captures were combined for other analyses.

Demographics

Sex ratios differed among treatments ($\chi^2 = 15.43$, $P >$ 0.01) and ratios were skewed towards males on clearcut treatments (fig. 2). The percentage of females that were gravid did not differ among treatments ($\chi^2 = 5.46$, $P = 0.2$).

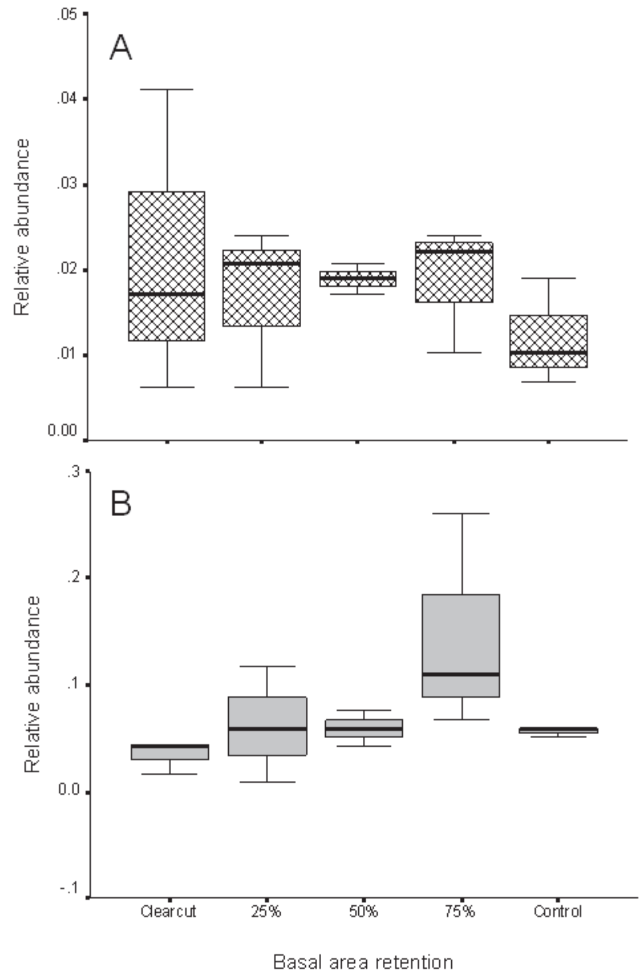

Figure 1—Relative abundance of eastern worm snakes across five tree retention treatments in northern AL, 2002-2005, as measured by drift fences (A) and coverboards (B).

No gravid females were observed on clearcut treatments. The sample percentage comprised of juveniles did not differ among treatments ($\chi^2 = 1.96$, $P > 0.9$) and these percentages ranged from 37 to 51 percent.

Body Size Characteristics

No obvious differences were detected in population structure among the five treatments (fig. 3). Populations on each treatment showed two size classes, one ranging approximately from 60 to 120 mm SVL and another from 140 to 240 mm SVL. Average log-transformed mass: length ratio for male worm snakes was highest in control treatments and lowest in 25 percent retention treatments ($F_{4,10} = 4.36$, $P = 0.031$; fig. 4a), while female log mass to length ratios did not differ among treatments ($F_{4,10} = 0.66$, $P = 0.628$; fig. 4b). A positive relationship (log mass: SVL = 0.024 + 0.428 basal area) was observed between log mass to length ratio of snakes and basal area of the plot of capture for male worm snakes ($R^2 = 0.19$, $P = 0.007$, $n = 37$; fig. 5a). No such relationship was observed for female worm snakes ($R^2 =$ 0.005, $P = 0.52$, $n = 54$; fig. 5b).

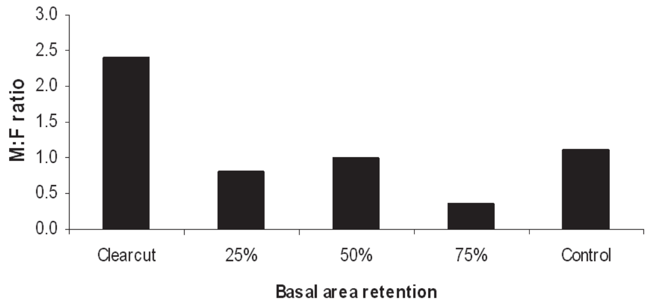

Figure 2—Sex ratios of eastern worm snakes across five tree retention treatments in northern AL, 2002-2005.

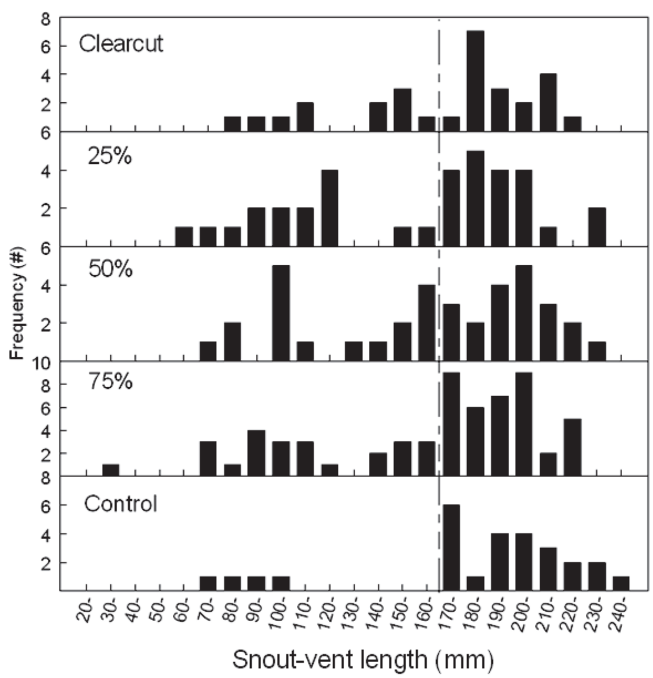

Figure 3—Histogram of size classes (snout-vent length) of eastern worm snakes across five tree retention treatments in northern AL, 2002-2005. Vertical dotted line represents cut-off for juvenile and adult size.

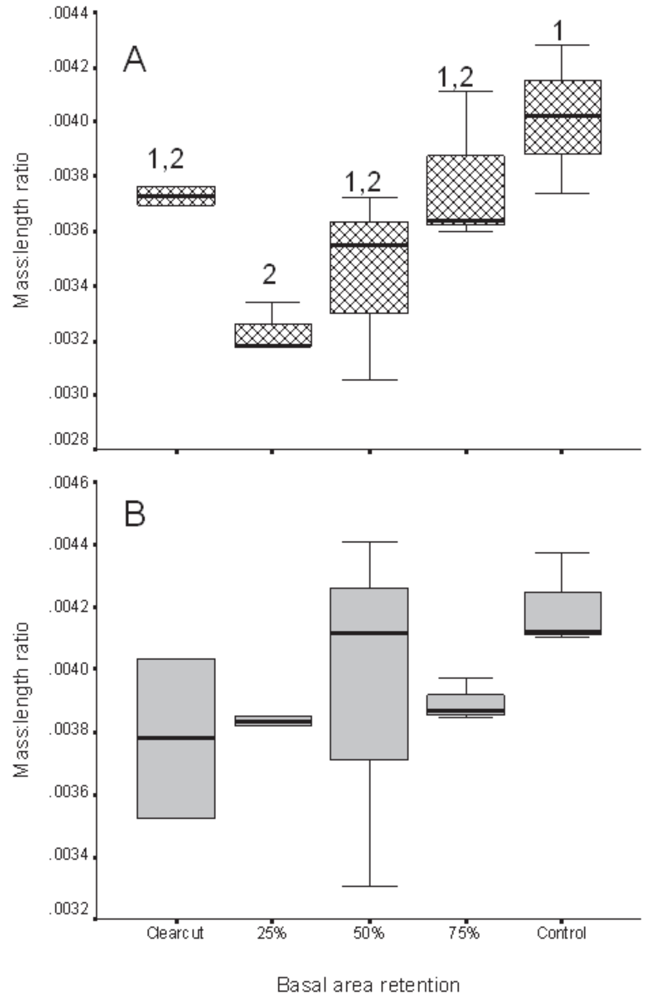

Figure 4—Average log-transformed mass: length ratio for male (A) and female (B) eastern worm snakes across five tree retention treatments in northern AL, 2002-2005.

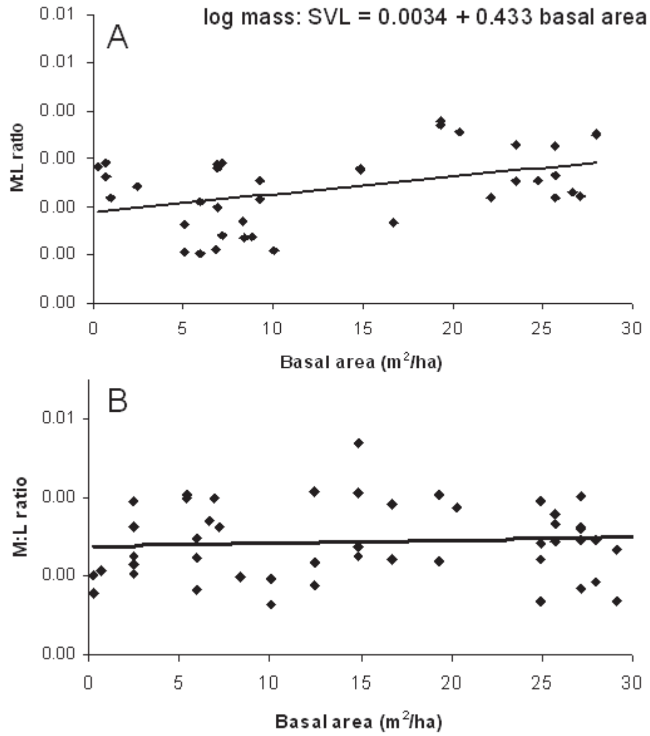

Figure 5—Average log-transformed mass: length ratio for male (A) and female (B) eastern worm snakes vs. average basal area (m^2/ha) at 45 measurement plots, northern AL, 2002-2005.

DISCUSSION

Relative abundance of eastern worm snakes did not differ among retention treatments. This species is often cited as preferring the litter layer in moist forests (Barbour 1960, Ernst and Barbour 1989), but it can also be common in open grassy fields near woodlands (Palmer and Braswell 1995). In KY, eastern worm snakes used recently cut areas and open banks as well as closed canopy areas (Barbour and others 1969). This wide range in habitat use might account for similar abundances of worm snakes across treatments in the present study. Greenberg (2001) found no difference in worm snake abundance between control stands and wind-created canopy gaps in NC.

Sex ratios of small snakes such as worm snakes are usually one male to every female (Clark 1970), but male-biased populations have also been found (Russell and Hanlin 1999). The high ratio of males to female we observed on clearcut treatments could have implications for population dynamics. The lack of gravid females on clearcut treatments suggests low recruitment in these areas. However, the overall high percentage of juveniles in our samples, including clearcut treatments, compared to previous studies (Parker and Plummer 1987) suggests that recruitment is taking place at healthy rates.

Canopy retention treatments were related to body size of male worm snakes. The average mass of a male snake at a given length was larger in control treatments than in 25 percent retention treatments. Also, there was a positive relationship between mass to length ratio and basal area. That is, at a given plot, male worm snakes are more massive at a given length when basal area is higher. This is the first report of such a relationship for a reptile species. This phenomenon is known for salamanders, with some species more massive per length on cut areas (Ash and others 2003, Knapp and others 2003) and other more massive on uncut areas (Karraker and Welsh 2006). It is unknown what, if any, implications these patterns could have for eastern worm snake populations. The differences could be an indication of growth rates or health of individuals. The main prey item of worm snakes is earth worms (Mount 1976), and the observed differences in body size observed in male snakes could be related to differences in worm snake abundance.

Tree harvesting at this geographic location and scale had subtle impacts on the demography of worm snake populations, but did not impact relative abundance of the species. Several aspects of this species uncovered during this study, including the significance of the two size classes present in samples, deserve further research.

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