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Factors affecting salamander density and distribution within four forest types in the Southern Appalachian Mountains

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Abstract

We used a terrestrial vacuum to sample known area plots in order to obtain density estimates of salamanders and their primary prey, invertebrates of the forest floor. We sampled leaf litter and measured various vegetative and topographic parameters within four forest types (oak-pine, oak-hickory, mixed mesophytic and northern hardwoods) and three age classes (0–12, 13–39, and ≥40 years) over two field seasons within the Wine Spring Creek Ecosystem Management area in western North Carolina. We found salamanders preferred moist microsites across all forest types with the highest salamander densities occurring on sites with a northern and/or eastern exposure and within northern hardwood forests. Salamander densities were lowest on 0-12-year plots, yet were equal on 13-39 and ≥40-year plots, suggestiug a much quicker recovery from the impact of clearcutting than reported by previous researchers. Overall invertebrate densities did not influence salamander density or distribution although, plots in which salamanders were captured, harbored significantly higher numbers of snails than plots in which salamanders were not captured. We discuss the importance of calcium to salamanders and snails as a possible source thereof.

Keywords: Salamander density; Invertebrate density; Southern Appalachian Mountains, Terrestrial vacuum

1. Introduction

Salamanders occur in many southern Appalachian habitats; however, factors influencing their density and spatial arrangement are not fully understood. Past research has looked at forest management (Pough et al., 1987; Ash, 1988; Petranka et al., 1993), soil pH (Wyman and Hawksley-Lescault, 1987; Wyman and Jancola, 1992), moisture and temperature of the forest floor (Heatwole, 1962; Jaeger, 1980; Wyman and Hawksley-Lescault, 1987), and vegetation and landform characteristics (Heatwole, 1962; Pough et al., 1987; DeGraaf and Rudis, 1990) as factors influencing salamander density and distribution within a variety of habitats. However, few researchers have examined the spatial relationship between salamanders and their primary prey – invertebrates of the forest floor.

Our study was initiated to examine abundance, biomass and diversity of macro-invertebrates of the forest floor and correlate that information with vegetation and topographic parameters. These data were collected as a part of study, investigating silvicultural strategies for improving wild turkey brood range. In addition to invertebrates, we incidentally captured salamanders in our leaf-litter samples. Consequently, we were able to look at the spatial relationship

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between salamanders and invertebrates of the forest floor, as well as surrounding vegetative and topographic parameters.

2. Methods and materials

This study was conducted on the Wine Spring Creek Ecosystem Management area (35°1 1′00″N, 83°36′30″W) and surrounding watersheds on the Wayah Ranger District in the Nantahala National Forest in western North Carolina. Mean annual precipitation for this area (≈4530 ha) during the study was 1917 mm and the mean annual temperature ‒ 10.4°C.

Based on continuous inventory stand conditions (CISC) silvicultural data obtained from the Wayah District Office, forests within the study area were placed into four broad types. These types were comprised of similar combined forest types, as designated by the USDA Forest Service: oak-pine (chestnut-oak–scarlet-o& chestnut-oak-scarlet-oak-yellow-pine, upland-hardwoods-white-pine, white-pine–upland-hardwoods, and white-pine); oak-hickory (white-oak-northern-red-oak-hickory, northern red oak); mixed mesophytic (cove-hardwoods–white-pine–hemlock, hemlock-hardwoods, yellow-poplar–white-oak-northern red oak); and northern hardwoods (sugar-maple-beech-yellow birch). Forest types were divided into three age classes (O-12, 13-39, ≥40 years), thereby creating 12 strata. All stands had been subjected to even-aged forest management, using clearcutting as the regeneration method.

Vegetative characteristics and topographic parameters (i.e. aspect and elevation) were measured within each stratum using 0.04 ha circular plots. Plots were located randomly within each stratum, with the number of plots per stratum determined by the amount of the study area encompassed by age class. Percentage herbaceous cover by lifeform (i.e. forb, fern, grass, etc.) was determined by the line intercept method (Smith, 1990), using three transects (11.3 m) radiating from plot center to plot perimeter at 0", 120" and 240°C. In addition, litter depth was recorded with a metric rule at four locations within each plot, and canopy coverage was recorded with a densiometer (Lemmon, 1957) at the center, top and bottom (according to slope) of each plot. Understory woody stem (<1.4 m in height) density was recorded within a 40.0 m^2 circular plot nested at the center of each 0.04-ha plot.

Five leaf-litter samples were collected 15 m from each plot center at 0°, 60°, 120°, 240" and 300°C. These five samples per plot were treated as subsamples and averaged; thus, each 0.04-ha plot was our sampling unit for invertebrates and salamanders. Leaf-litter samples were collected via vacuum using a 0.10 m^2 bottomless box with a lid (Harper and Guynn unpublished data). Each sub-sample was collected by a researcher, pacing 15 m out from the plot center and placing the box in front of him, thus capturing invertebrates within a known area. In order to avoid flushing flying invertebrates, the researcher would move slowly the last few paces, then quickly place the box on the forest floor. Next, the researcher would open the box lid while another worker would place the nozzle of the vacuum over the box. All vegetation, leaf litter, sticks and debris down to mineral soil, and fauna associated with those materials were vacuumed into cheesecloth sample bags.

The sample bags with content were oven-dried for 48 h at 60°C (Murkin et al., 1994). Content of sample bags was emptied into white trays under bright lighting, where salamanders and invertebrates were separated and picked from the litter using sieves and tweezers. Salamanders and invertebrates were then identified and weighed and the remaining litter content weighed. Sampling was conducted through June and July 1995 and 1996.

One hundred and twenty 0.04-ha plots were used to collect vegetation and topographic data. Six-hundred leaf-litter sub-samples were collected within these plots. According to area represented within the study site, five plots were measured within each 0–12-year forest stratum, 10 plots within each 13–39-year forest stratum, and 15 plots within each ≥40-year forest stratum.

Salamander density among all plots was tested for differences with respect to forest type and age class, using a chi-square test of independence, as well as, non-parametric Kruskal–Wallis procedure (SAS, 1990). Salamander density among all plots was tested for differences by aspect using ANOVA within the GLM procedure of SAS (1990). Because of heterogeneity of variances, salamander data were transformed by square root plus 0.5 (Steel and Torrie, 1980); however, results for transformed data were the same as for non-transformed data, therefore non-transformed densities are reported. Aspect was divided into four categories: N (316–45°), E (46-135"), S (136–225°), and W (226-315"). Pearson correlation coefficients were calculated for relationships between, salamander density, herbaceous cover, leaf-litter depth and weight and invertebrate density and weight using the CORR procedure within SAS. Also, plots in which we caught salamanders were tested against plots, where no salamanders were captured for differences in invertebrate abundance and biomass by invertebrate class using MANOVA within the GLM procedure. The univariate procedure within SAS was used to evaluate the distribution of invertebrate data, and Hartley's test was used to evaluate homogeneity of invertebrate variances. All invertebrate classes were distributed normally, except Isopoda (which was skewed low because of an absence from many plots); and all invertebrate classes displayed homogeneity of variances, except Isopoda and Gastropoda (which were slightly heterogeneous). Because of these cases of non-normality and unequal variances, all invertebrate data were transformed by square root plus 0.5 (Steel and Torrie, 1980), in order to meet the assumptions for MANOVA. Since the test results were identical for the non-transformed and transformed data, we present the non-transformed data for the clarification reasons. The significance level for all tests was p=0.05.

Table 1
Salamander densities (SE) on the Wme Spring Creek Ecosystem Management area

	Mean density per m^2
Forest type (# of plots)	
oak–pine (n=30)	0.4 (0.2)
oak-hickory (n=30)	0.9 (0.3)
mixed mesophytic (n=30)	0.7 (0.2)
northern hardwoods (n=30)	1.2 (0.3)
Age class	
0-12 (mean=5.8 years; range 3-12; n=20)	0.3 (0.2)
13-39 (mean=21.5 years; range 13–30; n=40)	0.9 (0.2)
≥40 (mean=78.8 years; range 40-135; n=60)	0.9 (0.2)
Aspect[a]	
north (n=27)	1.3 (0.4)A
east (n=25)	1.2 (0.4)A
south (n=36)	0.3 (0.1)B
west (n=32)	0.6 (0.2)A,B
overall (n=120)	0.8 (0.1)

*Densities with the same letter are not significantly different (p>0.05).

3. Results

A total of 48 salamanders were captured within the leaf-litter samples. Salamanders captured included, jordan's (*Plethodon jordani* n=32), mountain dusky (*Desmognathus ochmphaeus* n=8), seepage (*Desmognathus aeneus* n=7), and Blue Ridge two-lined (*Eurycea wilderae* n=1). Six classes of invertebrates were collected: Arachnida (including Acari, Amblypygi, Araneae, Gpiliones, and Pseudoscorpiones); Chilopoda (including Geophilomorpha, Lithobiomorpha, and Scolopendromorpha); Diplopoda (including Glomerida, Julida, Polydesmida, and Spirobolida); Gastropoda (including Pulmonata); Hexapoda (including Coleoptera, Collembola, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, Mecoptera, Neuroptera, Grthoptera, Plecoptera, Psocoptera, and Siphonaptera); and Malacostraca (including Isopoda).

Estimated density of salamanders was the highest in northern hardwood stands and lowest in oak-pine stands (Table 1); however, there were no significant (p=0.140) differences between forest types. Among age classes, estimated density within 13–39-year stands was equal to that in the ≥40-year stands (Table 1). The 0–12-year stands contained lower densities of salamanders, though not significantly (p=0.257) lower. The overall estimated density within the Wine Spring Creek Ecosystem Management area was 0.8 salamanders/m^2. Considering aspectwise mean salamander density decreased from areas with expected high moisture to areas with expected lower moisture (Table 1). A significantly (p=0.049) higher number of salamanders was found on north- and east-facing plots, as opposed to those with a southern aspect. There was no significant correlation between salamander density and leaf-litter depth (r-0.136; p=0.140; n=120), litter weight (r=0.088; p=0.341; n= 120), percent herbaceous cover (r=0.133; p=0.146; n=120), understory woody-stem density (r=0.137; p=0.138; n=120), or canopy coverage (r=0.075; p=0.416; n=120).

Table 2
Invertebrate densities (SE) and biomass (g) (SE) per m^2 within the four forest types on the Wine Spring Creek Ecosystem Management area

Invertebrate class[a]	Oak–pine	Oak-hickory	Mixed mesophytic	No. hardwoods
Arachnida				
density	6.0 (0.8)A	6.5 (0.9)A	6.3 (0.8)A	6.8 (0.9)A
biomass	0.0300 (0.0062)A	0.0373 (0.0056)A	0.0305 (0.0060)A	0.0393 (0.0075)A
Chilopoda				
density	7.5 (1.0)A,B	6.6 (1.1)A,B	4.7 (0.8)B	8.5 (1.2)A
biomass	0.0279 (0.0061)A	0.0317 (0.0074)A	0.0213 (0.0049)A	0.0283 (0.0050)A
Diplopoda				
density	21.1 (2.9)B	32.3 (6.1)B	44.6 (7.1)A	29.3 (4.3)B
biomass	0.4742 (0.0816)B	0.6067 (0.1232)A,B	0.9144 (0.1506)A	0.5663 (0.1090)B
Gastropoda				
density	54.6 (7.0)A	35.7 (5.9)B	59.5 (5.1)A	55.1 (6.9)A
biomass	0.9201 (0.2184)A	0.8266 (0.1787)A	1.2106 (0.2156)A	1.0539 (0.1907)A
Hexapoda				
density	26.3 (7.0)A	18.1 (2.4)A	15.6 (2.6)A	17.8 (1.6)A
biomass	0.1180 (0.0174)A	0.1262 (0.0196)A	0.1016 (0.0180)A	0.1536 (0.0273)A
Malacostmca				
density	4.3 (1.4)B,C	1.4 (0.5)C	5.2 (1.4)B	11.0 (2.9)A
biomass	0.0109 (0.0035)B	0.0040 (0.0015)B	0.0164 (0.0041)B	0.0310 (0.0092)A
Overall				
density	119.9 (10.3)A,B	110.6 (11.1)B	135.9 (9.8)A	128.5 (11.2)A,B
biomass	1.5811 (0.2571)A	1.6326 (0.2387)A	2.2947 (0.2345)A	1.8726 (0.2279)A

[a] Densities and biomass within each invertebrate class with the same letter are not significantly different ($p>0.05$).

Overall estimated invertebrate density was the highest within mixed mesophytic stands, though only significantly higher ($p=0.020$) than that in oak-hickory stands (Table 2). Various differences in invertebrate density and biomass were discovered among invertebrate classes according to forest type. Invertebrate density decreased with stand age (Table 3). Overall invertebrate abundance was significantly higher ($p=0.035$) within 0–12 vs. ≥40-age stands. Also, estimated invertebrate biomass was higher in the O-12 than 13-39 or ≥40-year stands however, the difference was not significant ($p=0.299$). Significant differences among invertebrate classes by forest-stand age included higher densities of gastropods ($p=0.0001$) in 0–12 and 13–39-age stands than ≥40-age stands; and higher densities of isopods ($p=0.014$) in O-12 than ≥40-age stands (Table 3).

Among all strata, there was a significant positive correlation between salamander density and invertebrate density (~0.224; $p=0.014$; $n=120$). There was however, no significant relationship between salamander density and invertebrate biomass ($r=0.138$; $p=0.134$; $n=120$). By invertebrate class, there was a significant positive correlation between salamander density and arachnids (-0.194; $p=0.033$; $n=120$) and gastropods ($r=0.189$; $p=0.039$; $n=120$). When plots in which salamanders were captured ($n=33$) were compared to plots in which we did not capture salamanders ($n=87$), plots with salamanders contained significantly ($p=0.0058$) higher densities of invertebrates (Table 4). Among invertebrate classes, plots in which invertebrates were caught had a higher estimated density of all six invertebrate classes, including significantly ($p=0.0053$) higher densities of Gastropods.

4. Discussion

Our data show a preference by salamanders for moist site conditions. This should be expected as terrestrial salamanders require moist skin for gas exchange (Duellman and Trueb, 1986), and search-out moist micro-habitats along the litter-soil interface during dry conditions (Heatwole, 1962; Jaeger, 1980). Moist site conditions are common on northeastern exposures and lower portions of slopes in the higher elevations of the southern Appalachians. Accordingly, we found salamander densities to be the highest on

Table 3
Invertebrate densities (SE) and biomass (g) (SE) per m^2 within the three forest age classes on the Wine Spring Creek Ecosystem Management area

Invertebrate class[a]	Forest-age class		
	O-12	13-39	>40
Arachnida			
density	4.8 (0.9)A	6.5 (0.6)A	6.9 (0.7)A
biomass	0.0202 (0.0050)A	0.0371 (0.0059)A	0.0371 (0.0046)A
Chilopoda			
density	6.6 (1.3)A	7.4 (1.0)A	6.5 (0.7)A
biomass	0.0170 (0.0046)A	0.0325 (0.0053)A	0.0273 (0.0044)A
Diplopoda			
density	42.0 (9.9)A	24.0 (2.7)B	33.6 (3.9)A,B
biomass	0.5338 (0.0962)A	0.4886 (0.0880)A	0.7771 (0.0987)A
Gastropoda			
density	57.6 (7.4)A	67.1 (6.0)A	38.5 (3.7)B
biomass	0.6873 (0.301 l)A	1.2640 (0.1978)A	0.6873 (0.1009)B
Hexapoda			
density	19.7 (3.5)A	19.9 (4.4)A	19.1 (2.6)A
biomass	0.0995 (0.0143)A	0.1369 (0.0171)A	0.1253 (0.0170)A
Malacostraca			
density	9.8 (2.5)A	6.3 (2.2)A,B	3.5 (0.7)B
biomass	0.0286 (0.0078)A	0.0167 (0.0068)A,B	0.0105 (0.0019)B
Overall			
density	i40.5 (14.3)A	131.1 (9.1)A,B	108.2 (7.2)B
biomass	2.1261 (0.3569)A	1.9758 (0.2316)A	1.6646 (0.1436)A

[a] Densities and biomass within each invertebrate class with the same letter are not significantly different ($p>0.05$).

plots (across forest types) with northern and eastern exposures (Table 1).

Slopes with a southern aspect receive more direct sunlight annually are therefore, hotter and the litter layer drier. On our study site, oak-pine stands are predominant on these drier slopes and present additional adverse conditions for salamanders. Soil aud leaf-litter pH is generally lower within stands with a large conifer and/or ericaceous shrub (e.g. *Kalmia latifolia*, which is abundant within oak-pine stands on our study site) component (Foote and Jones, 1989, DeGraaf and Rudis, 1990). Soil pH, between 3.5 and 4.0 may limit salamander distribution and continued exposure can be lethal (Wyman and Jancola, 1992). In addition, the litter layer in coniferous stands usually is thinner (DeGraaf and Rudis, 1990), and thus, dries more rapidly than deeper deciduous litter layers. In South Carolina, considerably fewer salamanders were captured within pine stands than in oak-hickory stands (Bennett et al., 1980), and Wyman and Jancola (1992) reported higher densities of amphibians in a beech (*Fagus grandifolia*) than in coniferous forests in New York. This factor also may influence salamander densities within the mixed mesophytic stands, we sampled, as hemlock (*Tsuga canadensis*) was common in the overstory (present in 19 out of 30 plots).

Salamanders were abundant, particularly, within northern hardwood forests on our study area. Northern hardwood stands in our study area averaged 1391 m in elevation and occurred on broad, north-facing slopes. Soil moisture was not measured on our plots, yet from our leaf-litter samples, it was evident that the litter layer within northern hardwood stands was never ‘dry’, providing salamanders with a hospitable environment. Pough et al. (1987) discovered above-ground activity of salamanders was positively correlated with leaf-litter depth in upland forests of New York. A deeper litter layer may retain moisture longer, especially when facilitated by microtopographical features, and can influence the horizontal distribution of salamanders (Heatwole, 1962). We did not find a significant positive correlation between salamander density and leaf-litter depth, however, we did not have an ah-coniferous stratum as did Pough et al. (1987).

Table 4
Invertebrate densities (SE) and biomass (g) (SE) per m^2 within the plots where salamanders were caught and plots where no salamanders were caught on the Wine Spring Creek Ecosystem Management area

Invertebrate class[a]	Plots with salamanders	Plots without salamanders
Arachnida		
density	7.5 (0.8)A	5.9 (0.5)A
biomass (g)	0.0356 (0.0060)A	0.0337 (0.0037)A
Chilopoda		
density	7.6 (1.0)A	6.6 (0.6)A
biomass (g)	0.0357 (0.0056)A	0.0241 (0.0034)A
Diplopoda		
density	37.5 (5.2)A	29.7 (3.2)A
biomass (g)	0.6709 (0.1159)A	0.6288 (0.0714)A
Gastropoda		
density	65.6 (5.9)A	45.8 (3.7)B
biomass (g)	1.1360 (0.1917)A	0.9523 (0.1181)A
Hexapoda		
density	20.1 (3.9)A	19.3 (2.4)A
biomass (g)	0.1210 (0.0201)A	0.1264 (0.0123)A
Malacostraca		
density	6.9 (1.8)A	4.9 (1.1)A
biomass (g)	0.0203 (0.0054)A	0.0138 (0.0033)A
Overall		
density	145.1 (9.9)A	112.2 (6.1)B
biomass (g)	2.0196 (0.2313)A	1.7791 (0.1424)A

[a] Densities and biomass within each invertebrate class with the same letter are not significantly different ($p>0.05$).

Within the leaf-litter layer, salamanders play a crucial role in the food web and nutrient cycles of many forest communities (Burton and Likens, 1975). Detritivores are the main prey for salamanders, thus salamanders help to maintain diversity within invertebrate populations of the forest floor and thereby facilitate litter decomposition. On our study area, overall invertebrate densities were high in all forest types and forest-age classes, with few significant differences. Because of this, we do not believe salamanders are limited by invertebrate abundance, or that salamanders inhabit particular forest types because of invertebrate populations. However, we do believe that abundance of certain invertebrates (e.g. snails) may be an influencing factor on salamander distribution within otherwise suitable habitats in the Wine Spring area.

As ectotherms, salamanders are particularly efficient at converting nutrients and biomass of low-order detritivores into a package for larger animals. As much as 60% of the energy ingested by salamanders is converted into new biomass. Average protein concentration of terrestrial salamanders is · 50%, making salamanders a highquality energy source for predators (Burton and Likens, 1975).

Our data suggest terrestrial salamanders on the Wine Spring area search out microsites with a high density of gastropods. Burton and Likens (1975) provide evidence supporting the notion snails are an important constituent in the diet of salamanders. Burton and Likens (1975) reported average calcium (Ca) content in salamanders is higher than that of all their prey except for gastropoda, diplopoda, and oribatid mites. Percentage Ca in gastropods was higher than any other prey item for salamanders at 25%; diplopods consisted of 15% Ca; and oribatid mites, 3%. No other invertebrate prey of terrestrial salamanders even approached 1% Ca. In order to reach a high Ca level, salamanders would have to consume a certain amount of prey with even higher Ca levels. This could explain why, across all forest types and age classes, plots on which we captured salamanders contained significantly higher numbers of snails than plots where salamanders were not caught. Burton (1976) studied feeding habits of four species of Plethodontidae and the land stage of *Notophthalmus viridescens* (Salamandridae), and found all five species preyed upon snails.

Diplopods were not as abundant in the diets of salamanders studied by Burton (1976) as gastropods or oribatid mites. This may be because of prey size. If the size of prey dictates what is eaten by salamanders, then prey density is a more important parameter than prey biomass in terms of habitat quality for salamanders. The majority of diplopods, we collected, were considerably larger (on the order of 4–5*x*) than the gastropods collected. Roughly, average diameter of snails, we collected, was <10 mm. All mites (order Acari) captured were grouped into arachnida. Although estimated densities of arachnida and diplopoda were higher within plots on which we caught salamanders, as opposed to plots where salamanders were not caught, the relationship was no!: significant (Table 4).

When compared with studies conducted in similar stand types, our salamander density estimates are fairly consistent with estimates from area-constrained searches (Heatwole, 1962, 0.4/m^2; Jaeger, 1980, 2.2/

m^2; Wyman and Jancola, 1992, 0.37/m^2) and slightly higher than those of surface-count estimates (Burton and Likens, 1975, 0.30/m^2; Ash, 1988, 0.18/m^2; Petranka et al., 1993, 0.33/m^2). Although definitive conclusions cannot be made regarding salamander density and habitat use, our data suggest that salamander populations recover quickly from stand disturbance (i.e. clearcutting). Estimated salamander density in stands 13–39-year old was equal to that in older (≥40 years) stands (Table 1). The average age of stands sampled in the 13-39 age class was 21.5 years (SE=0.7). This recovery rate is much faster than 50-70 years indicated by Petranka et al. (1993).

Ash (1988) searched two recently clearcut (year following) and two mature forest plots in western North Carolina and found significantly fewer salamanders on recently clearcut plots. Litter abundance, soil moisture and changes in prey abundance were listed as possible factors contributing to lower salamander populations on recently harvested areas. Average litter depth in 0-12-year plots (2.3 cm) was significantly less (p=0.0001) than that of 13-39 and ≥40-year plots (3.1 and 3.4 cm, respectively). This could lead to reduced litter moisture which would affect the density and distribution of terrestrial salamanders. Prey, however, was not a limiting factor for salamanders within 0-12-year plots (Table 3).

5. Conclusions

Collecting leaf-litter samples via vacuum was an efficient sampling method, as it permitted us to collect a large number of-samples and sift through the contents after drying when time permitted. We used a 0.10 m^2 box for sampling, because our intention was to capture and obtain density estimates for invertebrates only. With this size box and number of samples taken, we were able to achieve reasonable bounds for our invertebrate density estimates. However, if sampling was conducted solely to obtain density estimates for salamanders, a larger box (e.g. 0.5 m^2) could be used and more samples taken to achieve smaller standard errors associated with mean density estimates. Live salamanders could be pulled from the leaf-litter samples within the sample bags quickly and easily. Salamanders captured with our vacuum were not harmed when sucked into the sample bag, thus future researchers using this method for sampling salamander populations could count and measure the animals, either in a field or in the lab before releasing them.

Results of our study concur with previous studies concerning the apparent preference for moist microhabitats by terrestrial salamanders. Sites with northern and eastern exposures provided a more hospitable environment for salamanders. These sites were exemplified within northern hardwood stands. While, invertebrates of the forest floor were quite numerous in all available habitats, salamanders seemed to be situated in microsites with higher densities of prey, especially snails. A physiological need for Ca may make. snails a necessary component in the terrestrial salamanders' diet. Our data support the notion that, microsite conditions have a greater influence on salamander density and distribution, than overall invertebrate density or biomass; however, density of certain invertebrates (e.g. snails) may have a bigger impact on salamander distribution than others.

Although, we cannot make definitive conclusions, the impact of clearcutting may not be as severe or long-lived in certain areas as some researchers believe. Future research should investigate, impacts of forest management practices with respect to stand type and aspect. Salamander populations may rebound post harvest more rapidly in areas with more suitable habitat (i.e. moist conditions) than on dry southern slopes where conditions already may be less than marginal (see Diller and Wallace, 1994).

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