Terrestrial Habitat use of Marbled Salamanders *Ambystoma opacum*: A Site-Specific Approach

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By

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Abstract

The terrestrial habitat use of Marbled Salamanders *Ambystoma opacum*: A site specific approach

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Habitat destruction, fragmentation and degradation have contributed heavily to the decline of amphibian populations such as Marbled Salamanders (*Ambystoma opacum*). Often, ambystomatid water resources are conserved without consideration for the equally important terrestrial habitat. This is partly due to a lack of information regarding the relationship between ecological succession, plant community composition, microhabitat and salamander abundance. Three sampling transects consisting of drift fence arrays, vegetation assessments and microhabitat surveys were extended 100 m into the terrestrial habitat surrounding a seasonal wetland at Beech Fork State Park in Wayne County, West Virginia. Principal components analysis was used to identify habitat gradients. Stepwise multiple regressions were used to develop predictive models for Marbled Salamander abundance using raw data and principal components. Models predicted much of the variation in my data set $r^2 = .9974$, .8804 for raw data and principal components respectively. Inverse Distance Weighting was used to explore spatial relationships between variables. This study suggests that Marbled Salamanders are associated with late seral forests, and a high abundance of microhabitat.

Acknowledgements

First I have to thank Dr. Pauley for allowing me to do my research my own way and always encouraging me to ask the question *why*. You have always been approachable, kind and willing to steer me in the right direction, but somehow you still found a way to let me make my own mistakes. Inevitably, you helped me to grow as a person and a researcher. Thank you for being so selfless and dedicating your life to students and conservation. You do not get nearly the credit you deserve for mentoring countless individuals and your hard work as the "Cheat Mountain Stalker". You truly are a man to emulate.

I also must express my sincere gratitude and respect to Dr. Evans for all his assistance in the lab and in the field. I am not your graduate student and yet you spent countless hours helping me identify what often amounted to a single leaf of grass (I still do not know how you do it). In the beginning, my vegetation surveys were ancillary to the main point of my project, but somewhere along the way, you have helped me to understand that plants and animals are intimately tied together in our ecosystem. Thank you for encouraging me when I was discouraged, and pushing me to see this through to the end. You influence my thoughts and behaviors more than you may know.

Thank you to Dr. Little, Dr. O'Keefe and Dr. Gilliam, Dr. Jones, Dr. Strait and Dr. Adkins for tolerating my often eccentric behavior and encouraging me to pursue my holistic research ideas. Just know that I ask why because I want to understand, and work hard because I truly care about conserving our world and achieving sustainability.

I also wanted to thank Dr. Hight for all of her support and encouragement throughout my tenure at MU. Somewhere between TAing your class and tending your garden you have become an extremely influential figure in my life. I cannot thank you enough.

I want to thank my Mom, Dad, and Sister and for always providing loving support and encouragement through all of this. Simply put, without you all, I would not be who I am. I know that I can always rely on you three to steer me in the right direction, and provide encouragement. Thank you for understanding when I was a kid and I frequently came home from the Massapequa preserves covered in mud, turtle in hand. Growing up in the suburbs of the New York City, I have grown accustomed to seeing seemingly unplanned urban sprawl and I have always wanted to do something about it.

Last but certainly not least, thank you to Eric Merriam, Justin Carpenter, Sean Collins, Casey Swecker, Aaron Giles, Conor Keitzer, Emmy Johnson, Amy Schneider, Amy Hamilton, Triston Bond, Tomi Bergstrom, Ashley Fisher, Kevin Saunders, Matt Graham, Eric Deifenbacher, Noah McCoard, Katy Pawlick, Kerie Corley, Scott albaugh, Tim Balwin, Casey Bartkus, Reid Downer, Justin Weiss, Brad Musser, Chad Harris and all my other peers that have contributed to this project. My project is as much yours as it is mine.

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Introduction:

Habitat destruction, fragmentation and degradation continue to threaten the persistence of amphibian populations such as Marbled Salamanders (*Ambystoma opacum*) (Dodd and Smith 2003, Collins and Storfer 2003). Mitigating anthropogenic threats to amphibians requires a detailed understanding of amphibian natural history (Pauley 2005). Despite a growing body of evidence on the importance of terrestrial habitats for ambystomatid salamanders, the affect of habitat composition on their movement patterns is poorly understood (Semlitsch 2008, Gamble et al. 2007, Gibbs et al. 1998).

Ambystomatid salamanders breed in seasonal wetlands, but spend the majority of the year in the surrounding terrestrial habitat (Hairston 1987). Adjacent terrestrial habitat contains foraging and over wintering habitat, and a means to avoid desiccation (Faccio 2003, Regosin et al. 2003, Rothermel and Luring 2005). Ambystomatid salamanders have been documented to move over 1000 m from their breeding site (Gamble et al. 2007), but these long distance movements are thought to happen as a series of shorter movements over a two to three year period (Semlitch 2008). Juvenile salamanders in particular are not well suited to travel long distances, thus habitat immediately adjacent to a wetland may be critical to the local persistence of salamander populations in a fragmented landscape (Semlitsch 2008). Yet, little is known about the relationship between plant species composition, microhabitat, and the abundance of salamanders in human impacted terrestrial habitats (Gibbons 2003, Jenkins et al. 2006). Here I address the following question. Do relative seral stage and microhabitat features affect the spatial distribution of Marbled Salamanders?

Methods:

Study site:

Data were collected at Beech Fork State Park in Wayne County, West Virginia. The study site centers on a relatively small depression that seasonally holds water (GPS N: 38.18.159, W: 82.19.889). Variable local topography, hydrology and human land use have resulted in a mosaic of vegetative seres and habitat features. I extended three sampling transects into distinct ecological communities (Figure 1) that includes a mid-late successional forest (Figure 2), an early successional forest (Figure 3) and an agricultural field (Figure 4).

Drift fence methods

Three pre-staked silt fence transects with pitfall traps were extended into the habitat surrounding a depression that seasonally holds water. Each pitfall trap contained a wet sponge, and was covered by a piece of plywood angled over the trap to help prevent desiccation of captured animals. Pitfall traps were checked daily. Vertebrate organisms and crayfish captured in pitfall traps were identified to species (except small mammals) and subsequently released on the opposite side of the fence. Marbled Salamanders were given a single toe tip by cohort (i.e., fence) to help provide a directional component of habitat use. Selected drift fence data presented are an aggregate of data collected from June 6, 2007 to December 7, 2007.

Vegetation Survey

In June 2007, 22 10-m² plots were established within zones to obtain a measure of vegetative structure and composition. Surveys were stratified in the field to detect as much variation in plant community as possible. Each 10 m² plot was subdivided into four 5 m² to sample trees and shrubs. Trees were defined as woody species >1 m tall with a corresponding diameter at breast height (DBH) of >5 cm, shrubs were defined as plants >1 m tall with a DBH of <5 cm, and herbaceous plants were defined as plants <1 m tall. Vines were classified and sampled as shrubs. Ground cover was estimated for shrubs that had an extremely high density (e.g., Multifloral Rose, *Rosa multiflora*). Basal area from each stem was calculated from DBH. Density of each species per plot was collected for shrubs. A species-area curve of the herbaceous layer was constructed for the surveyed habitat to ensure that much of the variation in the plant community was captured. To reduce observer bias all plant data were collected by one person. Voucher specimens of most plants observed are held on file at the Marshall University Herbarium.

Microhabitat Survey

Ninety-six 1-m² plots were established in July 2007 to assess microhabitat features pertinent to ambystomatid salamanders. To keep the sample per unit area equivalent between zones, plots were established in a ratio of 2:6:10:14 from the closest to farthest zones respectively. A random numbers table was used to produce compass headings and distances from the focal pool for plot locations. Numbers were picked until the headings and distances fell within the desired zone. Within each plot, leaf litter depth (LD-cm), horizontally oriented wildlife burrow density (HB-per m²), vertically oriented wildlife burrow density (VB-per m²), canopy cover (CC-%), and pH were measured.

Litter depth per m^2 was determined by averaging the depth of litter at the four corners and the center of each plot. Litter was removed and burrows were then counted. Canopy cover was estimated with a densitometer. Leaf litter was measured by averaging the LD at the four corners and the center of each plot. Plots were then cleared of leaf litter and debris to determine the abundance and dynamics of wildlife burrows. Based on the animals caught in pitfall traps in the area, burrowing activity was likely undertaken by Spadefoots (*Scaphiopus holbrookii*), Long Tailed Shrews (*Sorex cinereus)*, Short-tailed Shrews (*Blarina brevicauda*), Mice (*Peromyscus* spp) and Little-Brown Mud Bugs (*Cambarus thomai*) (Piccininni and Pauley, unpublished data). HB can be best described as "runway" type burrows that were roofed by litter or a thin layer of soil supported by rootlets. Observed HB were likely created by shrews and enlarged by salamanders habitat use (Semlitsch 1983). VB were defined as vertically oriented burrows, likely created by spadefoots, mice and crayfish. VB extended at least 3 cm below the surface of the soil. To reduce observer bias all measurements were taken by one person.

Statistical Analysis

Average capture rates of Marbled Salamanders and values for microhabitat per zone (Figure 1) were calculated for use in statistical analysis. To analyze the affect of vegetation composition on salamander abundance, tree data were aggregated according to shade tolerance categories (USFS-SYLVICS). Aggregate tree variables used in analysis were shade tolerant (ST), intermediately shade tolerant (IST), and shade intolerant (SI). In addition, shrub and sapling density and herbaceous ground cover per wetland indicator status were aggregated for analysis (USDA, NRCS 2008). Categories used for shrubs and saplings were wetland (WS-Obligate plus wetlands facultative), facultative shrubs

(FS) and upland shrubs (US-Facultative upland and upland associated). Categories created for herbaceous species were wetland herbs (WH-Obligate plus wetlands facultative), facultative herbs (FH) and upland herbs (UH-Facultative upland and upland associated) and invasive herbs (IH) (Harmen 1999).

Wetland shrubs and saplings (WS) was omitted from statistical analysis because there were few observations of this variable. Zone C consists of relatively late seral forest and a road. I reasoned that high salamander abundance in zone C (see results) was due to the late seral forest and not the road (Gibbs 1998); habitat data taken from the road were not included in statistical analysis.

Principal components analysis (PCA) was used to identify and characterize habitat structure gradients. PCA1 and PCA2 scores were then compared to the average abundance of salamanders per zone. A multiple stepwise regression was then used to test the hypothesis that habitat composition affects the abundance and distribution of Marbled Salamanders. Raw data was subjected to backwards stepwise regression. Principle components 1-4 were subjected to backwards and forwards stepwise regression. Models reported are default models.

Geostatistics

Inverse distance weighting (IDW) was used to produce spatially explicit images of selected data (Figure 5). IDW is an exact, deterministic technique that operates under the single assumption that values close to sampled points are more similar than those far away (Walker et al. 2007). IDW images were masked with a raster setting to limit interpolations to the sampling transects. Program defaults were used to produce stretched classifications. Pairs of pitfall traps, vegetative plots and microhabitat plots were georeferenced in Geographical Information Systems (GIS) to provide further spatial context to the discussion.

Results:

The species area curve of the herbaceous layer leveled off, suggesting that much of the variation in the plant community was sampled (Figure 6). This implies that vegetative data collected was representative of real world floral structure and composition. The majority of capture events of Marbled Salamanders were associated with zones C and D (Figure 7).

Principal components 1, 2, 3 and 4 explained 34.6%, 27.6%, 13.8% and 10% of the variation in the data set respectively. Variables that loaded together on PCA 1 with positive coefficients were those that are locally associated with the relatively late seral forest (i.e., CC, pH, HB, IMT, LD, US-Table 1). Variables that loaded together on PCA 1 with negative coefficients were those associated with the agricultural field or the relatively early seral forest community (FS, FH, IH, IT, UH, VB, WH-Table 1). I interpret PCA 1 to represent the gradient between the relatively late seral forest and the rest of the sampled habitat.

Only one variable on PCA 2 had a negative coefficient (UH-Table 1). UH abundance was spatially related to the agricultural field (Figure 8). This spatial relationship led me to interpret PCA 2 as the gradient between the forested transects and the agricultural field. No further biological interpretations were made from the rest of the principal components, because I interpret the rest of the unexplained variation to be the result of variation at a scale finer than zones, or the affect of unmeasured variables (i.e., auxiliary hypothesis-Hempel 1966). Comparing PCA 1 scores with PCA 2 scores highlighted environmental relationships between zones (Figure 9).

There was a strong positive correlation between Marbled Salamander abundance and PCA 1 scores (Figure 10). There was not any meaningful pattern of correlation between Marbled Salamander abundance and PCA 2 scores (Figure 11). Backward stepwise regression analysis for raw data variables suggests that the abundance of shade tolerant trees was the best overall predictor of Marbled Salamander abundance (Table 2). Backwards and forward stepwise regression analysis for variables reduced by PCA produced the same predictive model for salamander abundance (Table 2). Regression analysis of plots scores did not include PCA 2-4 in the predictive model which supports the interpretation of PCA 2.

IDW images of the spatial relationship between variables were consistent with those identified by PCA and multiple regression analysis. On the scale of the mapped area, Marbled Salamanders appeared to have the highest relative abundance in association with the greatest relative abundance of shade tolerant trees (Figure 12). Marbled Salamander habitat use appeared to be concentrated in the direct proximity of the focal pool, and ≈75-100 m away from the pool on transect 1 (Figure 13). Patterns of habitat use were consistent among age, sex, and re-capture status (Figure 14). Raw data used in analysis is available in tables 3,4,5,6 and 7.

Discussion

Seral stage and Marbled Salamanders

Marbled Salamanders have semi-permeable skin and are subject to rapid desiccation. For this reason, Marbled Salamanders likely seek a mesic environment. One may make the assumption that Marbled Salamanders would prefer areas that are close to the potentiometric surface (i.e., early seral forest). This relationship did not hold true at my site, as salamanders were most frequently detected upland in association with the relatively late seral forest. This counter-intuitive finding makes sense considering the seasonality of the environment in the relatively early and late-seral communities.

At my site, the early seral community is seasonally flooded during late fall rains and early spring runoff. This water is only temporarily available, leaving the community dry for much of the summer (i.e., the period of time when Marbled Salamanders are most active in terrestrial habitats). In the relatively early seral community, the water table is close to the surface, but Marbled Salamanders do not appear to have the burrowing ability to access this water (Semlitsch 1983). In contrast, the climate of the relatively late seral forest is less extreme, and environmental stressors are likely buffered by relatively abundant refugia (e.g., leaf litter).

The observed pattern of terrestrial movements of Marbled Salamanders offers an explanation that is consistent with their natural history and previously described terrestrial habitat associations (Faccio 2003, Baldwin et al. 2006 $_a$). Simply put, on the scale of my study site, Marbled Salamanders were most frequently detected in the terrestrial habitat that provides structural diversity. At my site, structural diversity is at its highest relative abundance in the relatively late seral forest (Table 8).

Microhabitat

Microhabitat is crucial to the terrestrial survivorship of Marbled Salamanders. Supporting the findings of Faccio (2003) and Regonsin (2003), the distribution of Marbled Salamanders at my site is spatially related to the abundance of horizontally oriented burrows. Horizontal burrows at my site appear to be function of the depth of the leaf litter, and the deepest litter is spatially associated with the relatively late seral forest. The relatively deep layer of leaf litter is probably maintained by the relatively thicker canopy cover of the relatively late seral forest (Table 3). In addition, upland forests do not experience the rapid decomposition rates of wetland habitats, which may also contribute to the relative depth of the litter.

Unlike Faccio (2003) and Madison (1997), no clear spatial relationship emerged associated Marbled Salamanders with vertically oriented burrows. It is important to note that I did not attempt to identify what organism created the observed burrows. Marbled salamanders may actively seek out a specific type of burrow. My findings do not refute the biological importance of vertically oriented burrows, but their distribution in the landscape suggests that they may not be limiting resources for Marbled Salamanders (at least locally).

Human land use and salamander capture frequency

Although my data says nothing about the distribution of habitat features or Marbled Salamanders before human alteration, the legacy affects of anthropogenic impacts are evident. Marbled Salamanders appeared to largely avoid the agricultural field which supports the evacuation hypothesis (i.e., salamanders actively seek suitable habitat-Semltisch et al. 2008). No juvenile salamanders were observed on the field which may be the result of direct mortality or avoidance behavior.

Notably, Marbled Salamanders at my site frequently crossed the road. This contrasts Gibbs (1998), who found that Marbled Salamanders largely avoided a road. This may be a result of site specific differences in the location of suitable terrestrial habitat in respect to breeding pool locations.

Metapopulation dynamics and the relative instability of wetlands

My data set leads me to propose the working hypothesis that Marbled Salamanders exhibit meta-population dynamics (Gamble et. al 2007), but the functional unit of the meta-population in a fragmented environment may be seasonal pools *and* discrete patches of suitable terrestrial habitat (Figure 15). This hypothesis is consistent with the spatial structure observed by (Trenham et al. 2001).

Water is life giving and essential for Marbled Salamander breeding, yet the availability of water is highly variable, and it has a capacity to alter ecosystem structure, function and dynamics (Dick and Gilliam 2007). Trees growing near the bottom of a hydrolic head are most often in a state of early succession, partly due to the disturbance of periodic inundation. In addition, trees growing in close proximity to the potentiometric surface often have a relatively shallow root system, and are relatively vulnerable to uprooting during storms. Downed trees open the canopy which helps maintain the community in a state of early succession.

In contrast to early seral communities, relatively late seral communities are usually more mesic, complex and stable (Odum 1969). The relative stability of the late seral community is demonstrated by a lack of invasive plant species (Figure 16). The observed terrestrial distribution of Marbled Salamanders in other spatial extents is probably tied to local successional processes, and successional processes are known by plant ecologists as a variable approaching a variable (Gilliam and Roberts 2003).

The reality may be that the terrestrial distribution of Marbled Salamanders is highly site specific, and cannot be well generalized across a landscape. For example, cypress trees have buttresses and knees that provide support and allow them to persist despite inundation and reduced soils; therefore cypress swamps are often in a state of late succession. Notably, Marbled Salamanders can be found in large numbers in cypress swamps during the non-breeding season (Personal observation, Frank Piccininni, Marshall University). Ultimately, understanding *local* patterns of habitat suitability may be the only way to develop effective conservation and management plans (Baldwin et al. 2006_b,USFWS 2002, USFWS 1999).

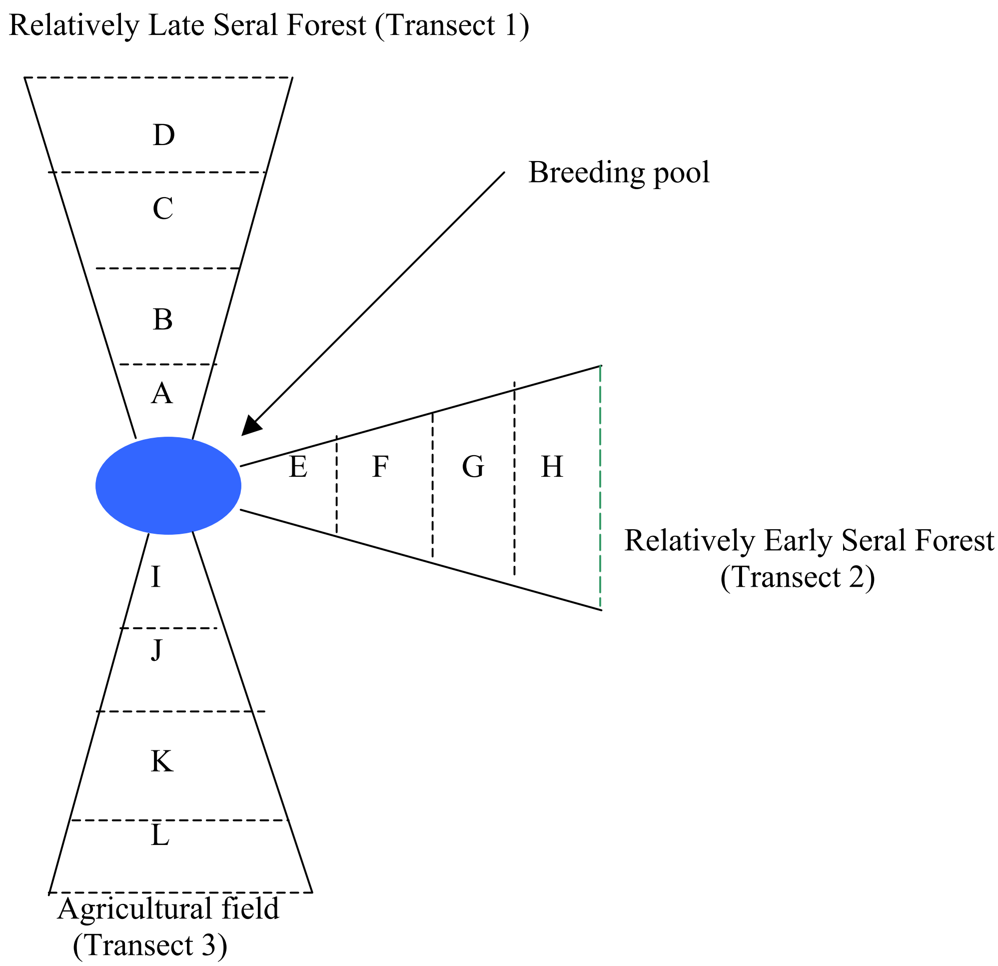


Figure 1: Idealized Sampling design and spatial configuration. Each transect (1-3) measures 100 meters. Drift fences (dashed lines) are spaced 25 meters apart. As distance from the pool increase the fences increase in size to sample an equivalent percent of area (~15.24, 30.45, 45.73 and 60.96 meters respectively).

Figure 2: Mid-late successional forest (Transect 1)

Figure 3: Early successional forest (Transect 2)

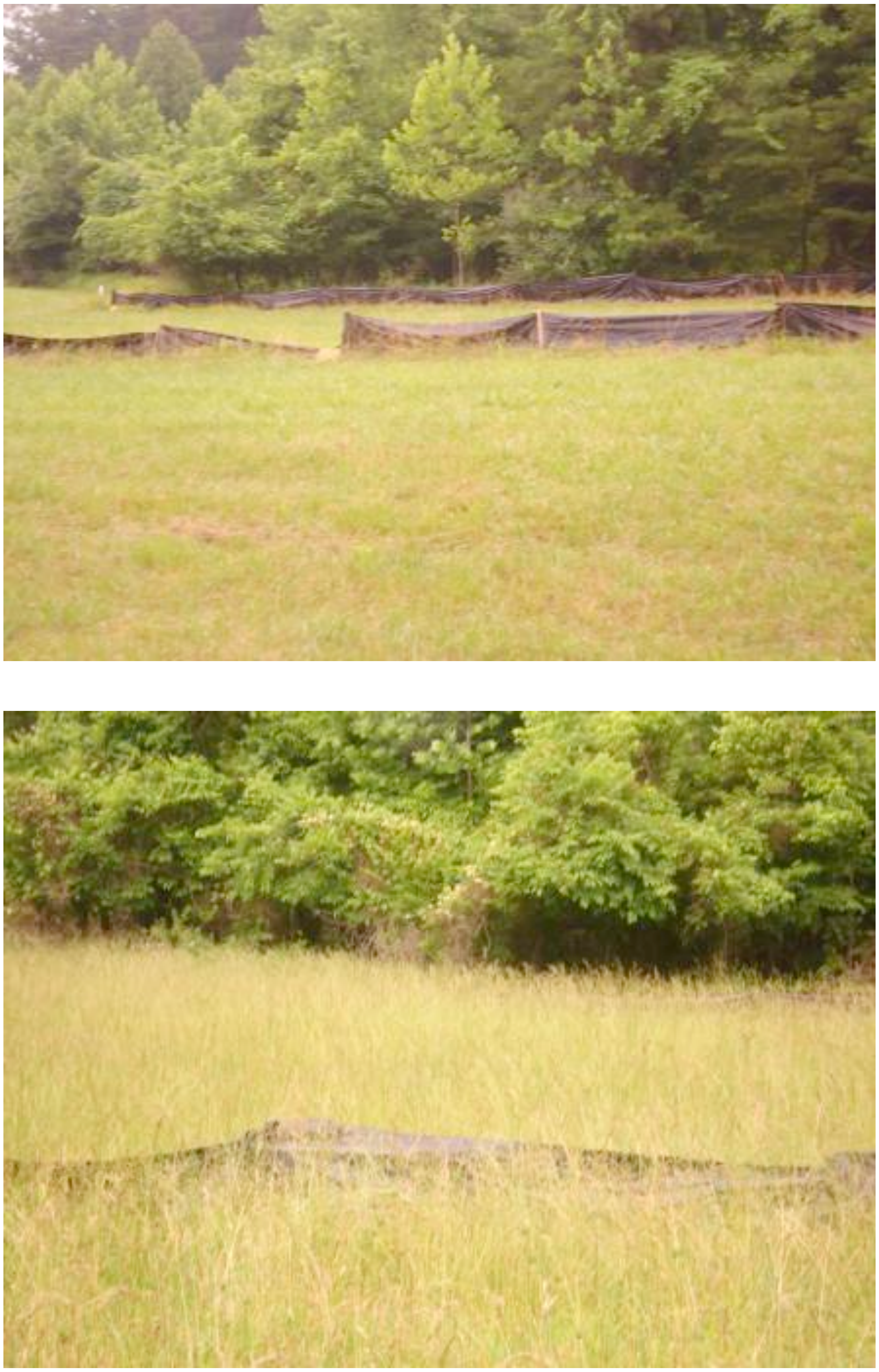
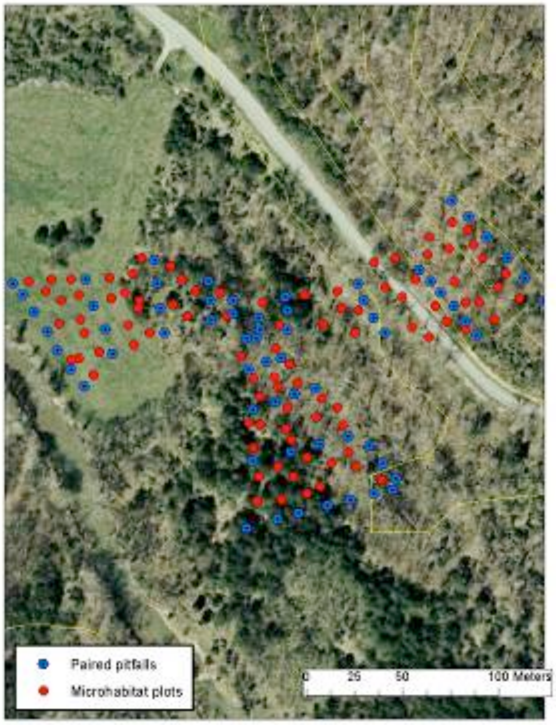


Figure 4: Agricultural field (Transect 3)


Paired pitfalls
Microhabitat plots
0
25
50
100 Meters

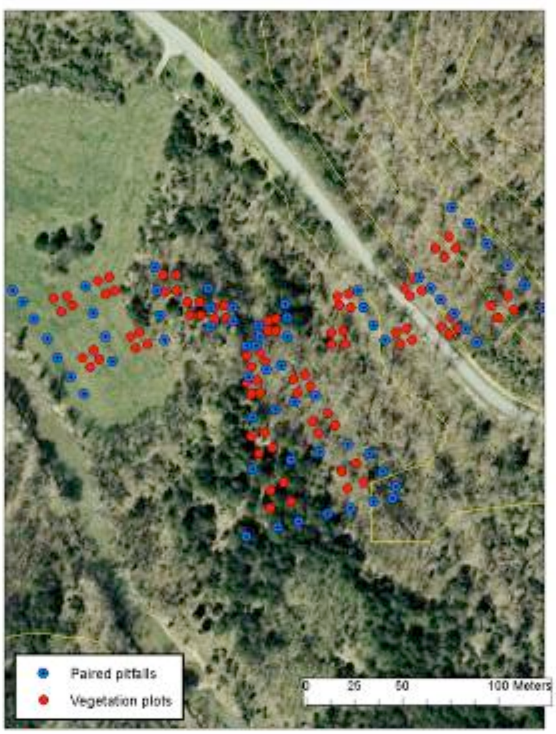

Paired pitfalls
Vegetation plots
0
25
50
100 Meters

Figure 5: Location of microhabitat plots and vegetative plots in respect to the spatial configuration of the drift fence array

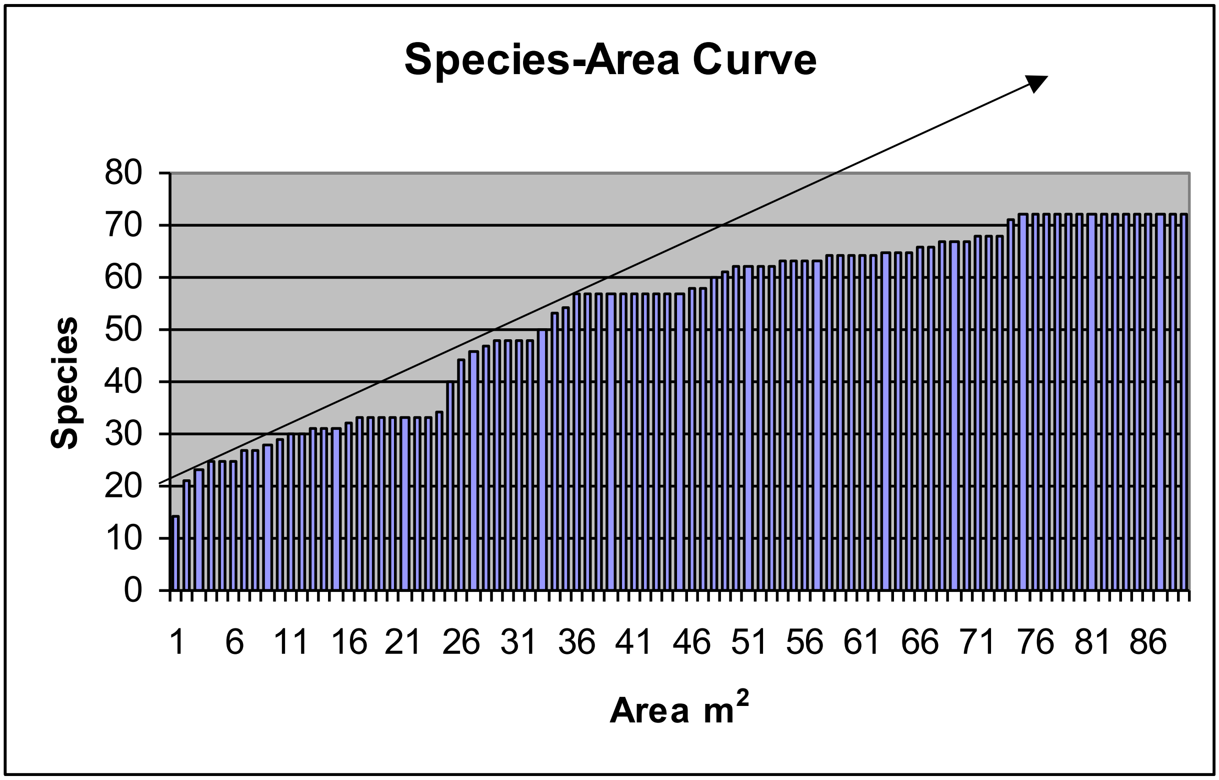


Figure 6: Number of herbaceous plant species plotted against area

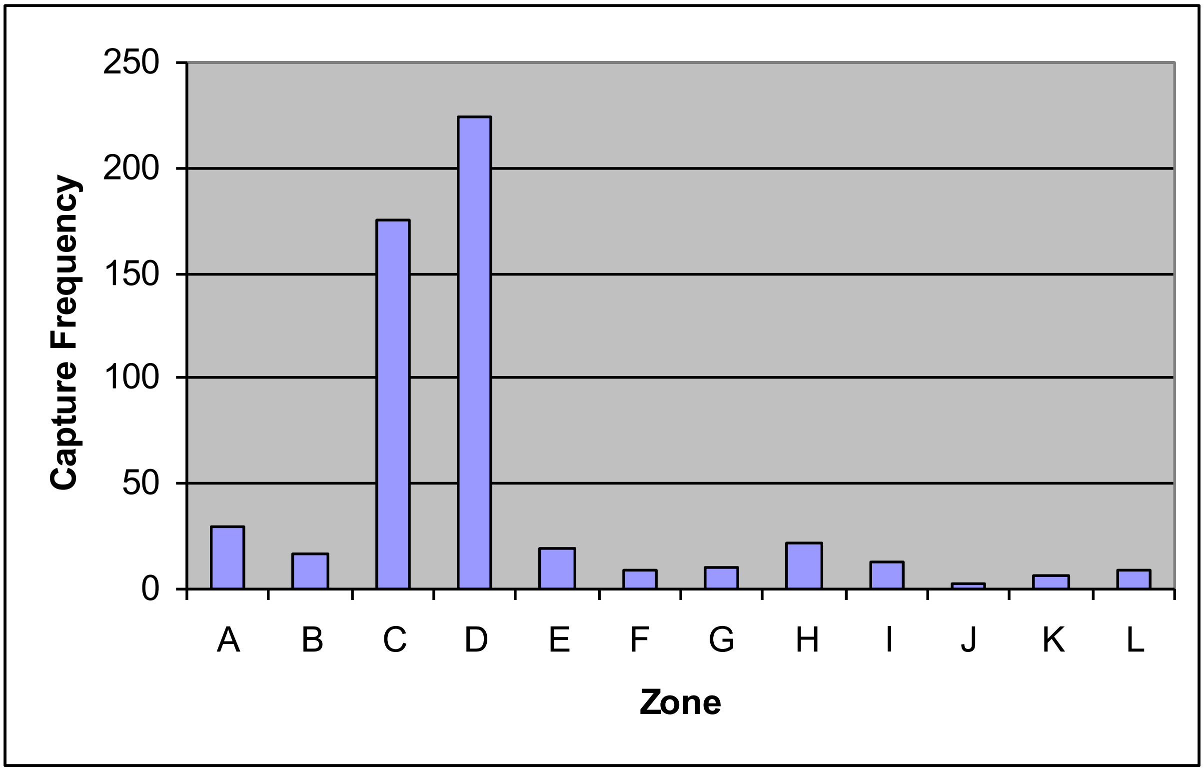


Figure 7: The frequency of Marbled Salamander captures per zone

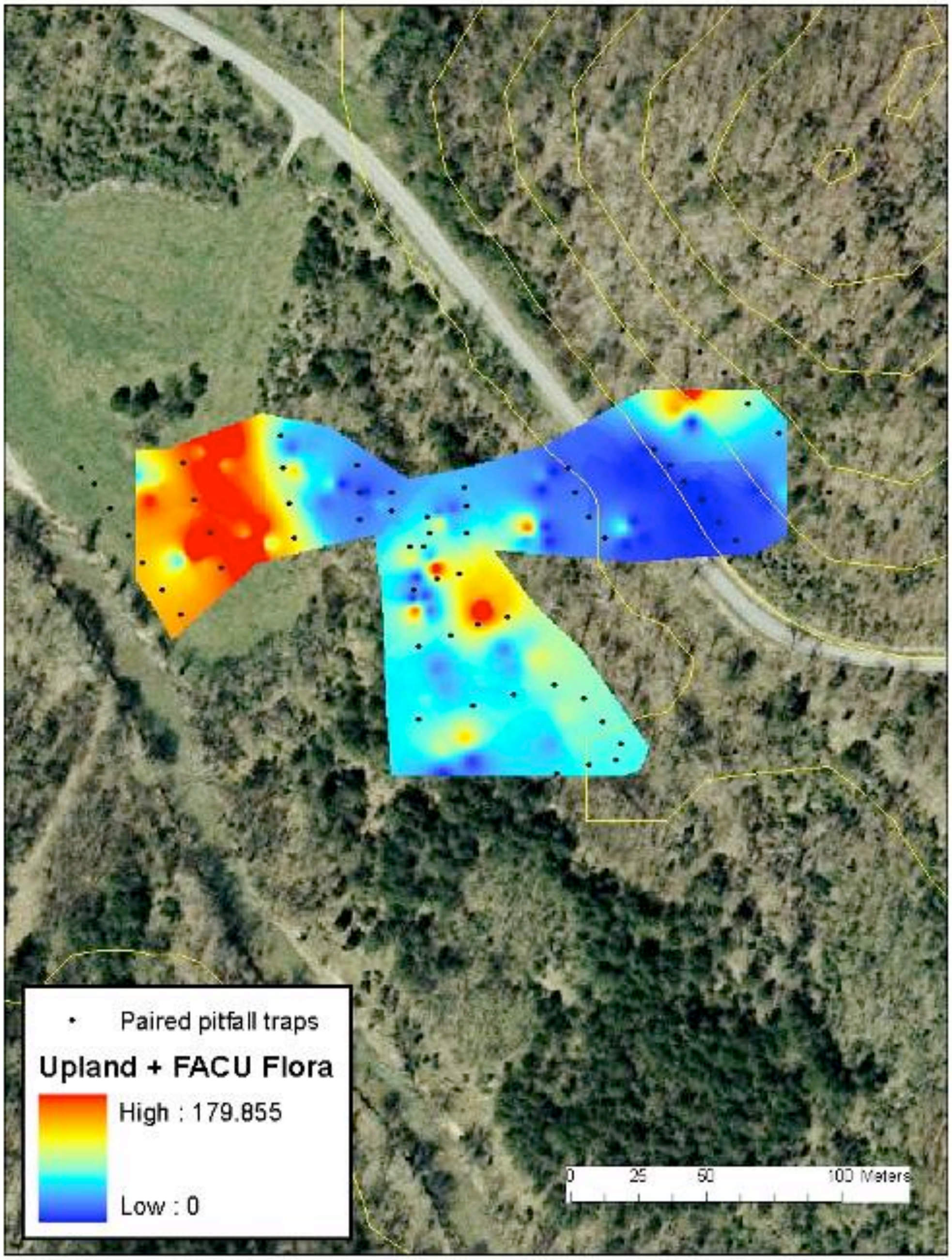


Figure 8: The spatial distribution of upland associated herbaceous flora

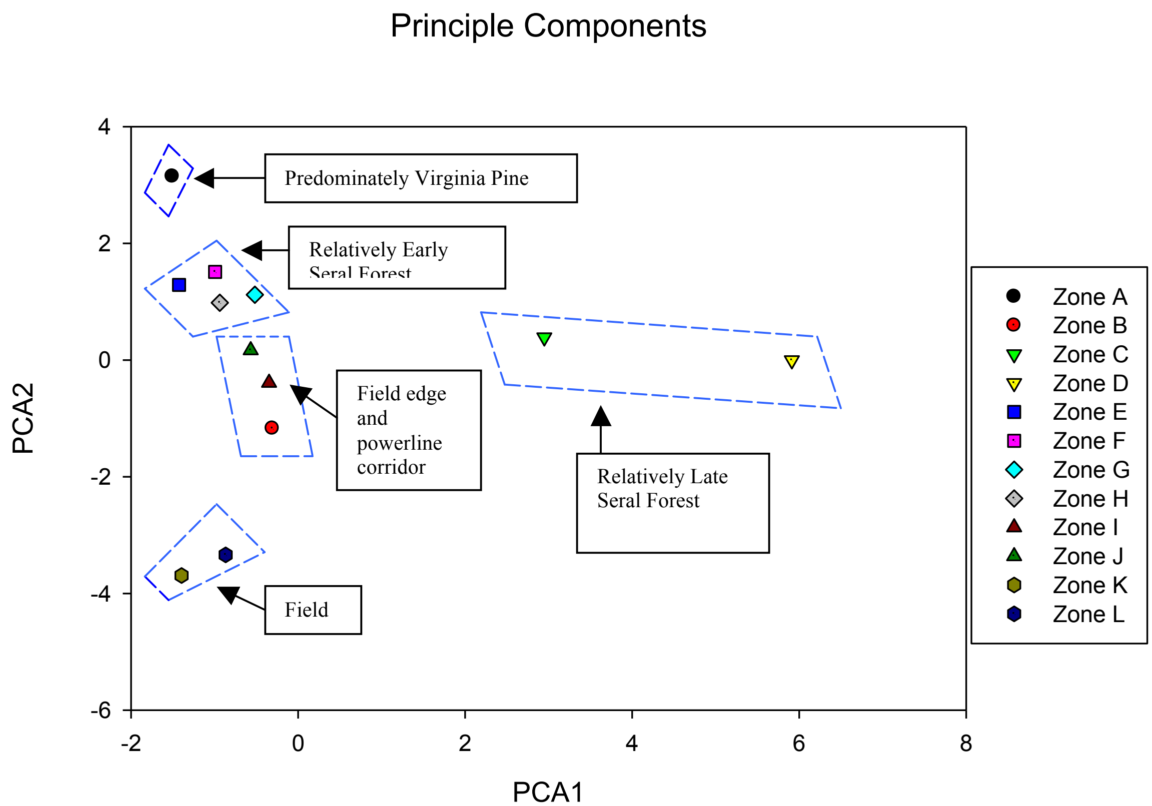


Figure 9. Results of principal components analysis of habitat variables

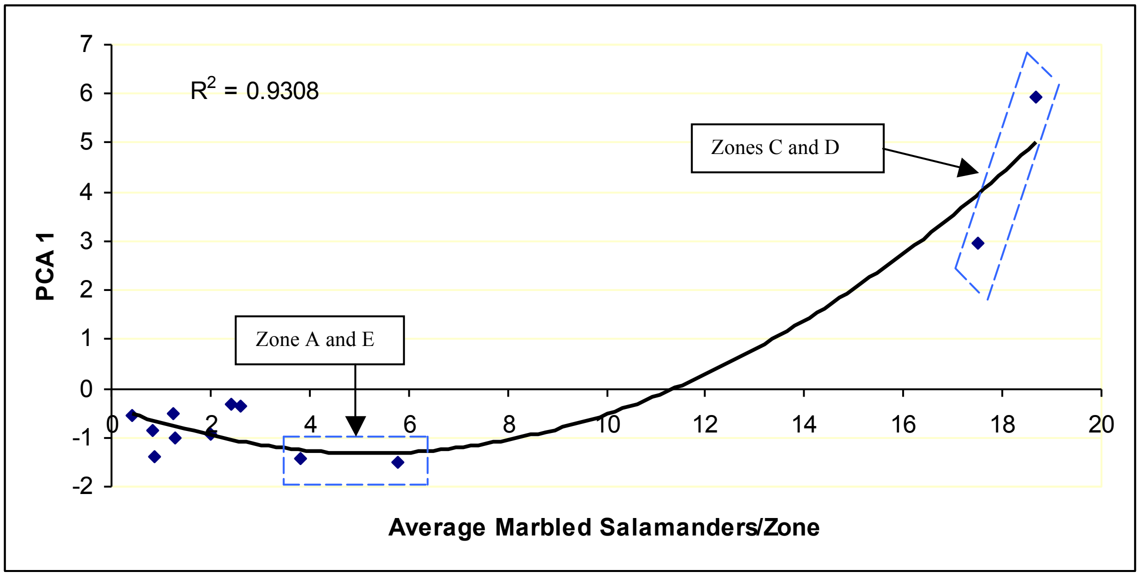


Figure 10: Marbled Salamander abundance vs. principal component 1

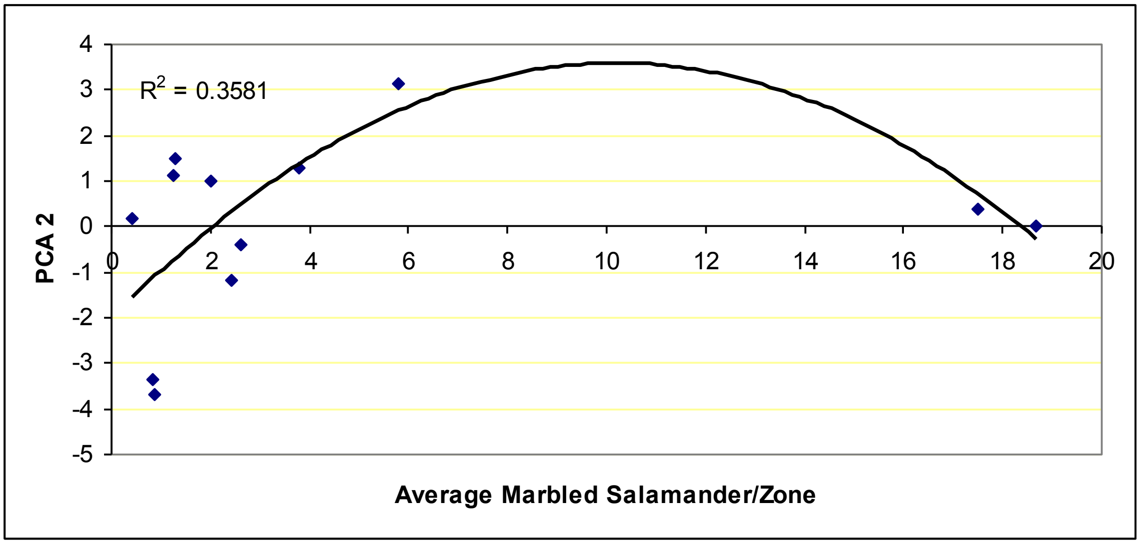


Figure 11: Marbled Salamander abundance vs. principal component 2

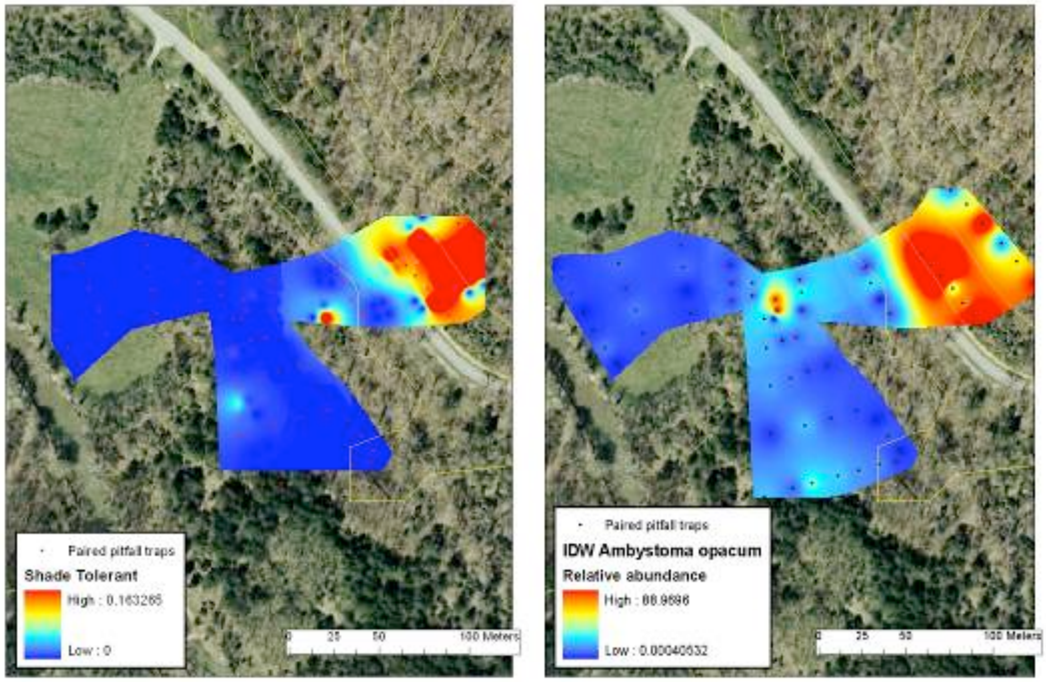


Figure 12. The distribution of shade tolerant trees (left) vs. the distribution of Marbled Salamander habitat use (right)

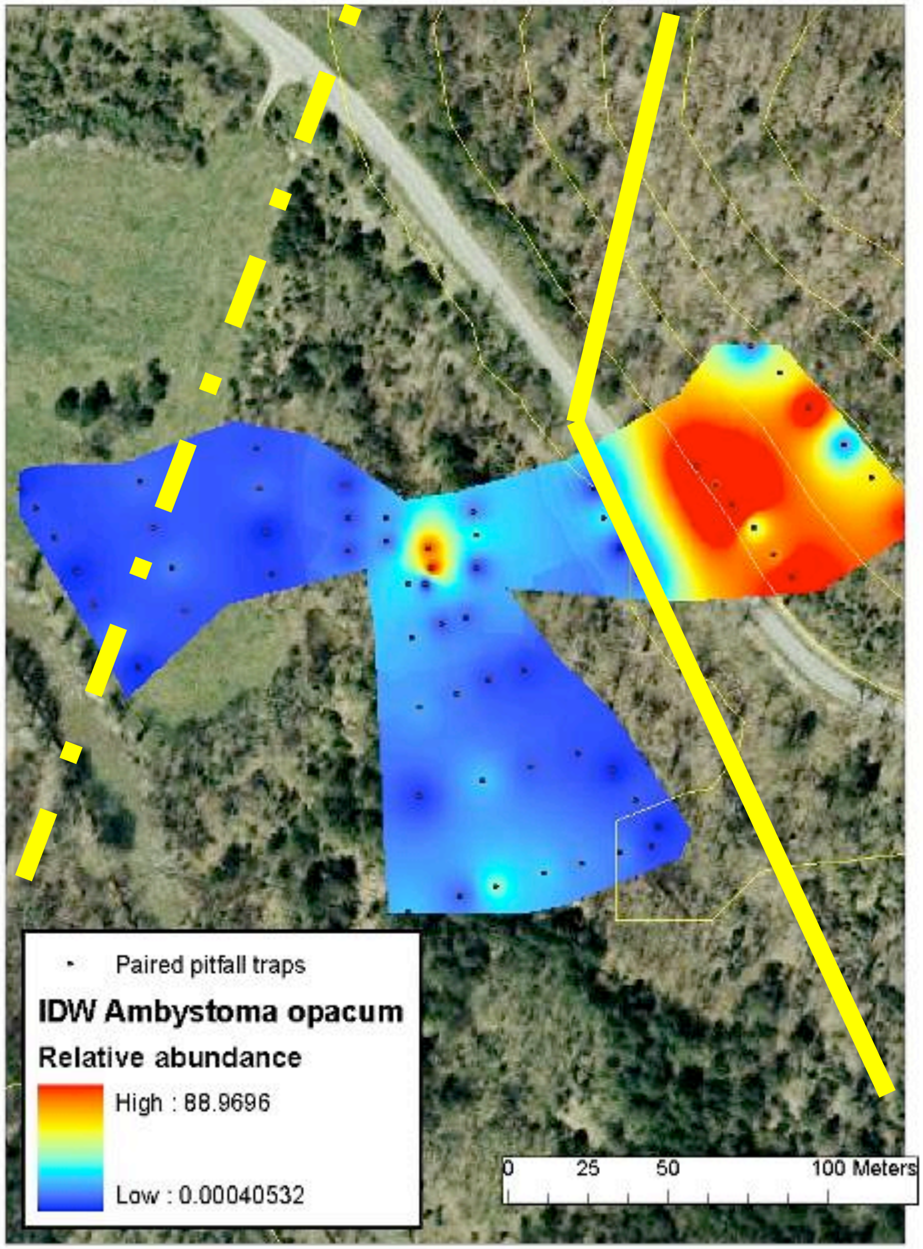


Figure 13: The spatial distribution of Marbled Salamander captures based on an aggregate of all data across age and sex classes. The solid line represents the approximate location of a powerline and the dashed line represents a buried gas line. N=755

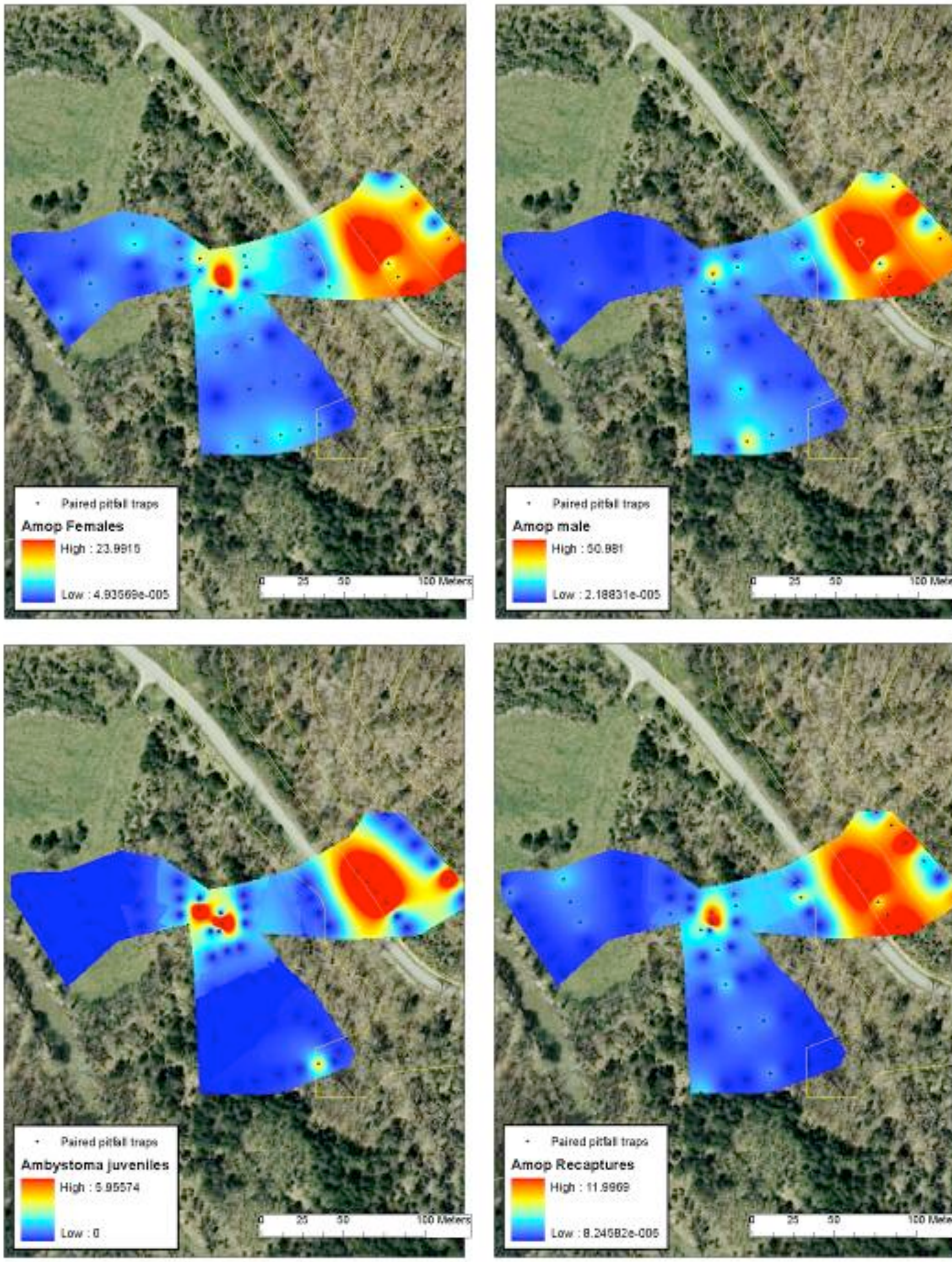


Figure 14: A spatial model of aggregate Marbled Salamander habitat use broken down by sex, age class and re-capture status. N=343, 221,22 and 119 for males, females, juveniles and recaptures respectively.

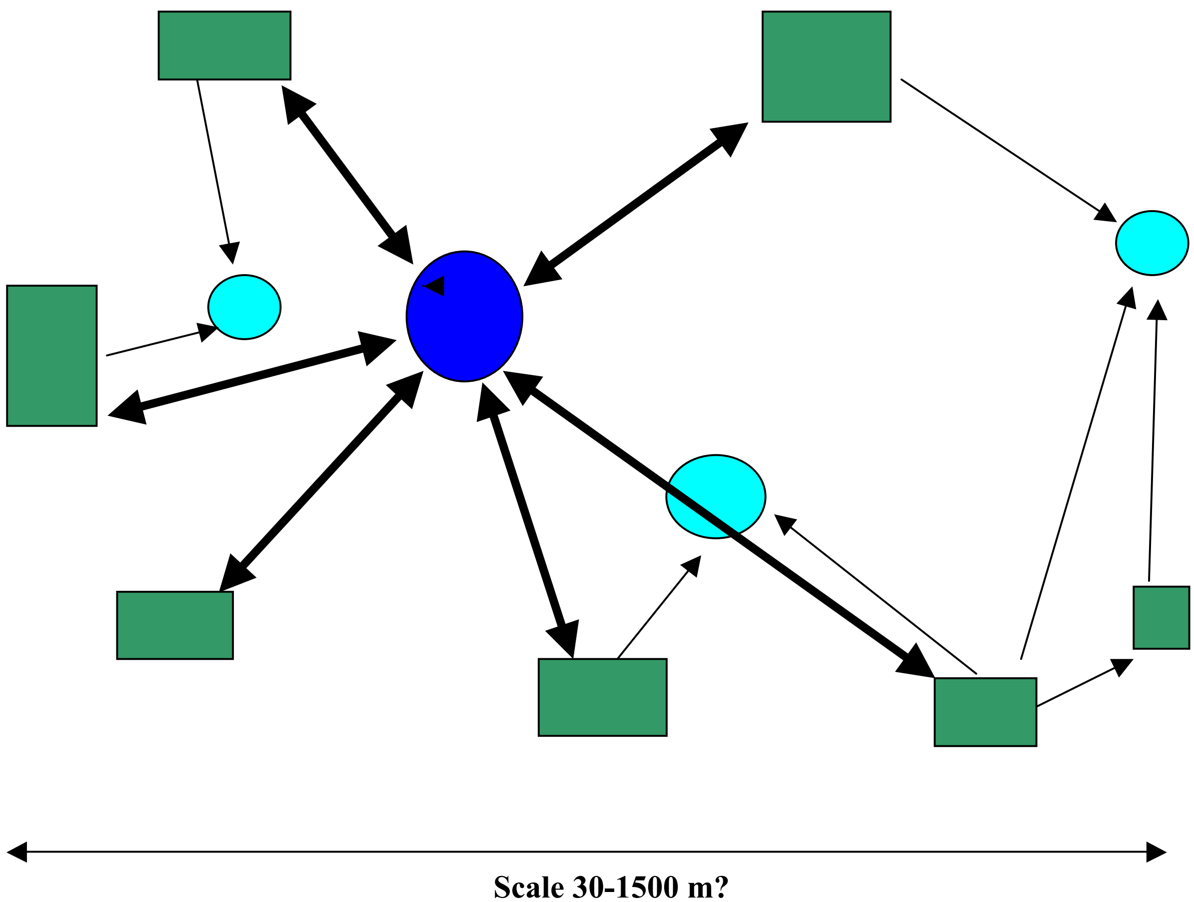


Figure 15: A conceptual model of the movement of Marbled Salamanders that assumes a loyalty to discrete patches of ideal terrestrial habitat. The dark blue circle represents the focal pool, light blue circle represent additional pools in the landscape, and the green rectangles represent discrete patches of suitable terrestrial habitat. Two way arrows represent juvenile egression and subsequent breeding migrations and one way arrows represents dispersal to other breeding ponds. Movement probably does not happen all at once. This model accounts for philopatry, metapopulation dynamics, and an ability to adapt to ever-changing water resources.

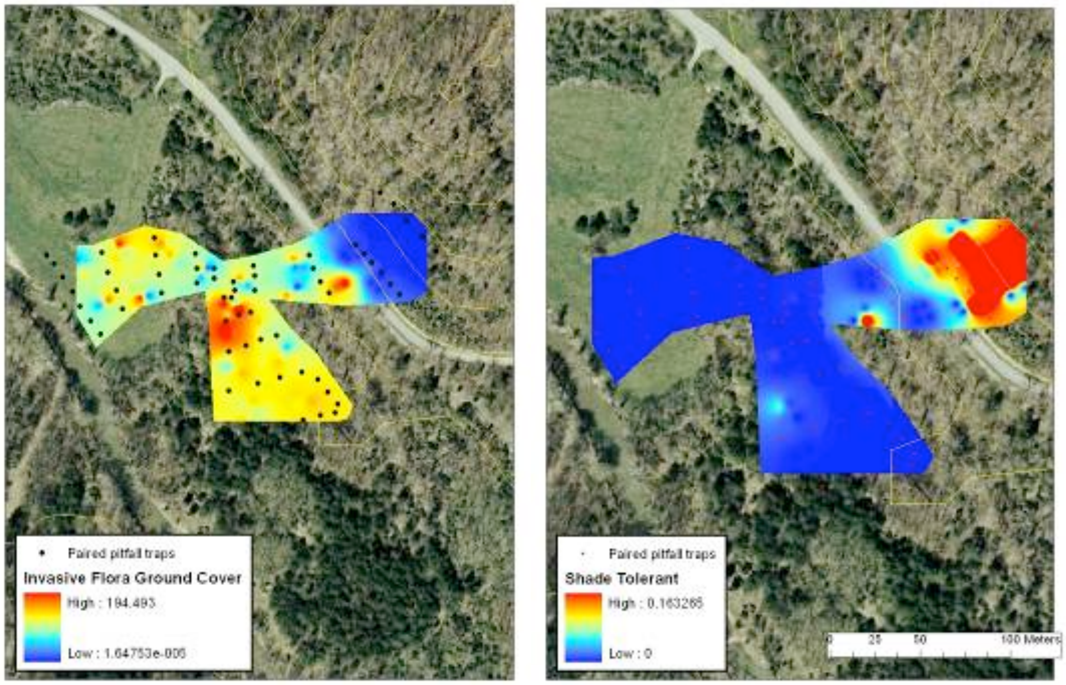


Figure 16. The distribution of Invasive Herbs vs. the distribution of Shade Tolerant Trees.

Variable	PCA 1	PCA 2	PCA 3
Canopy Cover	0.1294	0.4524	-0.0493
Facultative Shrubs	-0.1772	0.3948	-0.0441
Facultative Herbs	-0.1638	0.335	0.0264
Horizontal Burrows	0.4374	0.0236	0.0048
Invasive Herbs	-0.3905	0.0456	0.2275
Intermediately Shade Tolerant Trees	0.357	0.0244	0.0963
Intolerant Trees	-0.0815	0.3806	-0.0208
Litter depth	0.3773	0.1785	0.1046
pH	0.1988	0.2374	0.5027
Shade tolerant trees	0.4461	0.0073	0.0227
Upland Herbs	-0.1076	-0.3359	0.4488
Upland Shrub and Saplings	0.1341	0.0518	-0.5227
Vertical Burrows	-0.1027	0.3898	0.2966
Wetland Herbs	-0.162	0.1531	-0.3266

Table 1. Principal components (variable loading) of habitat variables produced by principle components analysis.

Backwards Stepwise Regression (Raw Data), r^2=.9923
Marbled Salamanders = .33699 + 2.87 HB_{mean} – 267.753 IST_{mean} + 361.135 ST_{mean} + 3.32 VB_{mean}
Backwards Stepwise Regression (Principal Components 1-4), r^2=.8208
Marbled Salamanders = 4.78783 + 2.62959 PCA1
Forwards Stepwise Regression (Principal Components 1-4), r^2=.8208
Marbled Salamanders = 4.78783 + 2.62959 PCA1

Table 2. Results of multiple regression analysis of raw habitat data and principal habitat components for Marbled Salamanders.

Zone	Amop	LD	CC	HB	VB	pH
A	5.8	0.72	87.65	0	1.5	6.34
B	2.42	1.42	26	0.166	0.166	5.9
C	17.5	1.98	80.708	1.2	0.6	6.37
D	18.67	3.05	94.21	2.78	0.28	6.54
E	3.8	0.84	86.09	0	1	6.48
F	1.29	1.12	89.12	0.33	0.83	6.36
G	1.25	1.54	89	0	0.6	6.27
H	2	0.98	86.37	0.142	0.36	6.19
I	2.6	0.15	80.37	0.5	0	5.96
J	0.429	0.37	75.35	0.67	0.33	6.12
K	0.875	0	2.33	0	0.2	6.11
L	0.82	0	0.64	0	0.14	6.19

Table 3: Raw microhabitat data. Amop= Average Marbled Salamanders/Zone, LD= Litter Depth, CC= Canopy Cover, HB= Horizontal Burrows, VB=Vertical Burrows, pH.

Zone	Amop/Zone	IH	UH	WH	FH	ST	IST	SI	WS	FS	US
A	5.8	75.63	0	25.625	91.9	0.000491	0	0.07931	0	3.75	0.5
B	2.42	69.06	17.5	52.5	83.44	0.0116	0.013	0	0	0.75	0
C	17.5	2.18	0	1.875	3.125	0.0351	0.0026	0.06541	0	0.25	6.625
D	18.67	0	38.625	0	52.8	0.052	0.0355	0.00701	0	0.25	3
E	3.8	132.5	48.75	18	196.9	0	0.00096	0.02554	0	1	1.75
F	1.29	122.8	57.625	25.56	155.63	0.000353	0.01091	0.07116	0	1.5	0.375
G	1.25	93.27	29.0625	17	105.63	0.0036	0.00443	0.07942	0.5	1.125	0.75
H	2	103.44	32.44	8.06	114.06	0	0.00166	0.10446	0	1.375	3.25
I	2.6	60	13.75	25.63	95.625	0.001662	0.00174	0.03255	0	1	11
J	0.429	90	22.5	15	132.44	0	0.00756	0.03216	0.125	1.375	4.25
K	0.875	105.71	106.875	0	0.3125	0	0	0	0	0	0
L	0.82	71.9	72.5	0	0	0	0	0	0	0	0

Table 4: Raw vegetative data. IH=Invasive Herbs, UH=Upland Herbs, WH=Obligate +FACW, FH=Facultative Herbs, ST=Shade tolerant trees, IST=Intermediately Shade Tolerant Trees, SI= Shade Intolerant Trees, WS=Wetland Shrubs, FS=Facultative Shrubs, US=Upland Shrubs.

Tree Species	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H	Zone I	Zone J	Zone K	Zone L
Acer negundo	0.0005	0.0071	0	0	0	0	0	0	0.001048	0	0	0
Acer rubrum	0	0.0017	0	0.004	0	0	0.0087	0.0074	0	0	0	0
Carpinus caroliniana	0	0	0.022	0	0	0	0	0	0	0	0	0
Cornus florida	0	0	0	0.003	0	0.004	0.0223	0	0	0	0	0
Elaeagnus umbellata	0	0	0	0	0	0	0	0.0003	0	0	0	0
Fagus grandifolia	0	0	0.0534	0.047	0	0	0	0	0	0	0	0
Fraxnus americana	0	0	0.0038	0.002	0	0	0	0	0	0	0	0
Liriodendron tulipfera	0.0064	0	0	0	0.0123	0.009	0.0073	0.032	0	0.006	0	0
Platanus occidentalis	0	0.016	0	0	0.01	0.011	0.0043	0.0017	0.002	0.008	0	0
Pinus virginiana	0.073	0	0.0398	0.004	0.01	0.002	0.035	0.0654	0.033	0.018	0	0
Quercus alba	0	0	0.0017	0.035	0	0	0	0	0	0	0	0
Ulmus rubra	0	0.0064	0.0016	0	0	0	0.0005	0	0	0	0	0

Table 5: Basal area per tree species per zone

Sapling and Shrub Species	Zone A	Zone B	Zone C	Zone D	Zon e E	Zone F	Zone G	Zone H	Zone I	Zone J	Zone K	Zone L
Aeculus octandra	.25	0	0	.5	.25	0	0	0	0	0	0	0
Acer rubrum	0	0	.167	.25	0	0	.375	0	0	0	0	0
Acer negundo	2	.5	0	0	.75	.625	.125	.25	0	.125	0	0
Betula nigra	0	0	0	0	0	0	.125	0	0	0	0	0
Carpinus caroliniana	0	0	1	.125	.25	0	.25	0	0	0	0	0
Cornus florida	.25	0	.83	0	0	.25	.5	1	.25	0	0	0
Elaeagnus umbellata	0	0	0	0	1.5	0	0	1.625	10.7 5	3.12 5	0	0
Fagus grandifolia	0	0	1.58	2	0	0	0	0	0	0	0	0
Fraxnus Americana	0	0	.417	.375	0	0	0	0	0	0	0	0
Liriodendron tulipfera	.25	0	0	0	0	0	0	0	0	0	0	0
Juniperus virginiana	0	0	.167	0	0	0	0	0	0	0	0	0
Lonicera japonica	0	0	0	0	0	.125	0	.5	0	0	0	0
Parthenocissus quinquefolia	0	0	0	0	0	.125	0	.625	0	.5	0	0
Platanus occidentalis	0	0	0	0	.25	0	.5	0	0	.125	0	0
Rhus radicans	7.75	.125	0	0	0	.5	.625	.125	1.5	1.12 5	0	0
Quercus alba	0	0	.417	0	0	0	0	0	0	0	0	0
Ulmus rubra	.75	.125	0	0	0	.375	0	.25	.5	.125	0	0
Vitis sp.	.875	.125	0	0	0	0	0	0	5.25	3.12 5	0	0

Table 6: Sapling and shrub density per zone

Herbaceous Species	Zone A	Zone B	Zone C	Zone D	Zon e E	Zone F	Zone G	Zone H	Zone I	Zone J	Zone K	Zone L
Boehmeria cylindica	2.5	1.25	0	0	5.63	14.69	7.5	5.31	9.38	12.5	0	0
Lonicera japonica	8.125	9.06	19.58	0	16.6	24.38	11.56	4.06	15	22.5	0	0
Microstegium vimeneum	62.5	22.5	22.7	0	75	71.25	77.5	95	45	55	0	0
Panicum clandestinum	10	17.81	20.83	0	37.5	29.38	6.25	4.375	.312 5	27.5	0	0

Table 7: Selected herbaceous species ground cover per zone

Habitat Type	Canopy Cover (%) $p < .0001$, $F=538.32$, $N=57$	Litter Depth (cm) $p < .0001$, $F=29.47$, $N=57$	Horizontal Burrows/m2 $p < .0001$, $F=20.23$, $N=57$	Vertical Burrows/m2 $p = .657$, $F= 0.43$, $N= 57$
Relatively Late Seral	90.66a	2.77 a	2.37 a	.37 a
Relatively Early Seral	82.44b	.77 b	.16 b	.26 a
Hay Field	.47c	0 b	0 b	.16 a

Table 8: A Bonferroni one-way ANOVA comparing sample means of selected habitat data.

Literature Cited:

Baldwin R.F., A.J.K. Calhoun and P.G. deMaynadier$_a$. 2006. The significance of hydroperiod and stand maturity for pool-breeding amphibians in forested landscapes. Canadian Journal of Zoology. 84: 1604-1615.

Baldwin, R., A.J.K. Calhoun, and P.G. deMaynadier$_b$. 2006. Conservation planning for amphibian species with complex habitat requirements: a case study using movements and habitat selection of the wood frog (*Rana sylvatica*). Journal of Herpetology 40:443-454.

Collins J.P. and A. Storfer. 2003. Global amphibian declines: sorting the hypothesis. Diversity and Distribution. 9: 89-98.

Dick D.A. and F.S. Gilliam. 2007. Spatial heterogeneity and dependence of soils and herbaceous plant communities in adjacent seasonal wetlands and pasture sites. Wetlands. 27 (4): 951-963.

Dodd C.K. and L.L. Smith. 2003. Habitat destruction and alteration: historical trends and future prospects for amphibians. Pp. 94-112 In Amphibian conservation. (ed.) R.D. Semlitsch. Smithsonian Institution Press, Washington D.C.

Faccio S.D. 2003. Postbreeding emigration and habitat use by jefferson and spotted salamander in Vermont. Journal of Herpetology. 37 (3): 479-489.

Gamble L.R., K. McGarigal and B.W. Compton. 2007. Fidelity and dispersal in the pond-breeding amphibian, *Ambystoma opacum*: Implications for spatio-temporal population dynamics and conservation. Biological Conservation. 139: 247-257.

Gibbons J.W. 2003. Terrestrial habitat: A vital component of herpetofauna of isoloated wetlands. Wetlands. 23 (3): 630-635.

Gibbs J. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management. 62 (2): 584-588.

Gilliam F.S. and M.R. Roberts. 2003. The dynamic nature of the herbaceous layer: synthesis and future directions for research. Pp. 323-337 *In* The herbaceous layer in forests of eastern North America. (ed) F.S. Gilliam and M.R. Roberts. Oxford University Press, Oxford.

Hairston SR., N.G. 1987. Community ecology and salamander guilds. Cambridge University Press, Cambridge.

Hempel C.H. 1966. The test of a hypothesis: Its logic and its force. Pp. 19-32 *In* Philosophy of Natural Science. (ed.) E. and M. Beardsley. Prentice-Hall, New Jersey.

Harmon P.J. 1999. Checklist of the invasive plant species of West Virginia. The West Virginia Native Plant Society.

Jenkins C.L., K. McGarigal and B.C. Timm. 2006. Orientation of movements and habitat selection in a spatially structured population of marbled salamanders (*Ambystoma opacum*). Journal of Herpetology. 40 (2): 240-248.

Madison D.M. 1997. The emigration of radio-implanted Spotted Salamanders, *Ambystoma maculatum*. Journal of Herpetology. 31 (4): 542-551.

Odum E.P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Pauley T.K. 2005. Reflection upon amphibian conservation. P.p. 277-281. *In* Amphibian Declines: The conservation status of United States Species. (Ed.) Michael Lannoo. University of California Press. Berkeley California.

Regosin J.V., B.S. Windmiller and J.M. Reed. 2003. Influence of abundance of small-mammal burrows and conspecifics on the density and distribution of spotted salamanders (*Ambystoma maculatum*) in terrestrial habitats. Canadian Journal of Zoology. 81: 596-605.

Rothermel B.B. and T.M Luhring. 2005. Burrow availability and desiccation risk of mole salamanders (*Ambystoma talpoideum*) in harvested versus unharvested forest stands. Journal of Herpetology. 39 (4): 619-626.

Semlitsch R.D. 1983. Burrowing ability and behavior of salamanders of the genus *Ambystoma*. Canadian Journal of Zoology. 61: 616-620.

Semlitsch, R.D., C.A. Connor, D.J. Hocking, T.A.G. Rittenhouse and E.D. Harper. 2008. Effects of timber harvesting on pond-breeding amphibian persistence: Testing the evacuation hypothesis. Ecological Applications 18 (2): 283-289.

Semlitsch, R.D. 2008. Differentiating migration and dispersal processes for pond-breeding amphibians. Journal of Wildlife Management 72:260-267.

Trenham P.C., W.D. Koenig, and H.B. Shaffer. 2001. Spatially autocorrelated demography and interpond dispersal in the salamander *Ambystoma californiense*. Ecology. 82 (12): 3519-3530.

USDA, NRCS. 2008. The PLANTS Database (http://plants.usda.gov, 24 March 2008). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

U.S. Fish and Wildlife Service. 1999. Endangered and threatened wildlife and plants; notice of intent to clarify the role of habitat in endangered species conservation. U.S. Federal Register. 64 (113): 31871-31874.

U.S. Fish and Wildlife Service. 2002. Sonora tiger salamander (*Ambystoma tigrinum stebbinsi*) recovery plan. U.S. Fish and Wildlife Service, Phoenix, Arizona. iv + 67 pp.