AMPHIBIAN POPULATION AND COMMUNITY CHARACTERISTICS, HABITAT RELATIONSHIPS, AND FIRST-YEAR RESPONSES TO CLEARCUTTING IN A CENTRAL APPALACHIAN INDUSTRIAL FOREST

by
Lori A. Williams

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APPROVED:

Dr. Carola A. Haas, Chair	Dr. Patrick D. Keyser
Dr. Dean F. Stauffer	Dr. C. Andrew Dolloff

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ABSTRACT

The overall goal of this project was to provide baseline data on amphibian species richness, relative abundance, and habitat use for a long-term landscape ecology study on MeadWestvaco industrial forest in the Allegheny Highlands of West Virginia. From results of area-constrained daytime searches (10 m x 10 m plots) across the landscape, I developed 9 regression models to predict amphibian relative abundance. I constructed models for each year for all plots on all habitat types, plots that were in a Stream Management Zone (SMZ), and plots that were in upland, or non-SMZ, habitat. Distance to perennial or ephemeral streams or perennial ponds (SMZ classification), the amount of available rocks along transects, and site index were the 3 most important habitat variables in models for all plots combined and were responsible for 24-32% of the inherent variation in population relative abundance. Other habitat variables that were significant in models were year, % canopy cover, the amount of available woody debris of decomposition classes 3-5 along transects, % woody stems ($\leq$7.5 cm DBH), soil pH, and % herbaceous vegetation. R^2_{PRESS} values for all 9 models ranged from 0.08 to 0.35. Amphibian relative abundance showed positive relationships with all significant habitat variables with the exception of year and % woody stems.

In natural cover object use/availability analyses, I discovered salamanders preferred rocks over woody debris, relative to the amount available of each. Salamanders preferred flat rocks to any other shape, flagstones to any other type of rock, and rock lengths in the 31-40 cm class. Preferred wood widths were in class 5-10 cm, while preferred wood lengths were in class <50 cm; salamanders exhibited strong preferences for wood in higher states of decomposition (class 3-5).

I provided baseline, preharvest data for 28-acre reference areas on 9 forest compartments scheduled for clearcuts. I sampled all 9 reference areas preharvest and sampled 3 during year 1 postharvest using coverboard and night plot surveys. On these 3 areas, species richness declined from preharvest to postharvest, but species diversity showed little change. Overall relative abundance declined significantly preharvest to postharvest with coverboard sampling ($p=0.0172$) and night plot sampling ($p=0.0113$). At coverboard stations, relative abundance declined significantly from preharvest to postharvest at a distance of 5-10 m ($p=0.0163$) and 40-50 m ($p=0.0193$) away from adjacent mature forest.

Finally, using Pianka's index, I compared the night plot and coverboard sampling techniques in terms of proportions of the 4 most common species captured. These sampling techniques on average were >80% similar for all reference areas.

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I would like to recognize and thank the funding sources that made this project possible, the MeadWestvaco Corporation and the National Council for Air and Stream Improvement (NCASI). I also extend many thanks to my advisor, Dr. Carola Haas, for her patience, insight, guidance, and especially the opportunity to work on this project and develop my career. Thanks go to the other members of my committee, Dr. Patrick Keyser of the MeadWestvaco Corporation for his help with field logistics and site information, Dr. Dean Stauffer for his assistance with data analysis and statistics, and Dr. Andy Dolloff for his advice on initial study design.

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PROJECT BACKGROUND

Project Goals and Justification

Although amphibians are increasingly the subjects of conservation focus in light of documented global declines in amphibian diversity and increases in physical deformations, they are rarely considered in forest management plans (Bury et al. 1980, Pough et al. 1987, Blaustein and Wake 1990, Wake 1991, Blaustein 1994, deMaynadier and Hunter 1995, Harlow et al. 1997, Pauley et al. 2000).

As described in the following paragraphs, amphibians make appropriate subjects for studying forest health and the effects of silviculture because of their sensitivity to habitat disturbance and changing microclimates, because of their limited dispersal ability compared to birds and many mammals, and because of their crucial role in the forest ecosystem (Heatwole 1962, Duellman and Trueb 1986, Wyman 1998, Welsh and Droege 2001).

The role of amphibians in the forest ecosystem is substantial because of their abundance and their contributions to the food web and in structuring the detritivore community. In eastern deciduous forests, terrestrial salamanders often make up the majority of vertebrate biomass, more than that of birds and equal to that of small mammals (Burton and Likens 1975, deGraaf and Yamasaki 2001). Amphibians consume small soil arthropods unavailable to larger vertebrates, thus converting that energy into biomass that larger predators can then utilize (Burton 1976, Pough 1983, Wyman 1998, Welsh and Droege 2001).

Amphibians, particularly lungless salamanders (Caudata, Plethodontidae) that respire cutaneously, are sensitive to changes in temperature and moisture conditions (Heatwole and Lim 1961, Feder and Pough 1975, Zug 1993, Pough et al. 1998, Welsh and Droege 2001). Timber harvesting directly impacts those habitat features by manipulating canopy, understory, and surface conditions. Higher temperatures and decreased moisture on the forest floor make conditions after timber harvest less suitable for salamanders that are prone to desiccation (Pough et al. 1987, Harpole and Haas 1999).

My research is the first stage for the amphibian component of a long-term Appalachian Landscape Ecology Project (ALEP) designed for the MeadWestvaco Wildlife and Ecosystem Research Forest (WERF) and adjacent industrial forest in Randolph County, WV. Sponsored by the MeadWestvaco Corporation and the National Council for Air and Stream Improvement (NCASI), this ongoing project is designed to monitor the effects of silviculture on wildlife, vegetation, and ecosystem health by manipulating the distribution of forest age-classes within a landscape through replicated experiments.

I have initiated the amphibian component of the ALEP with 2 years of field research, the main goal being to provide baseline, preliminary data on preharvest and postharvest amphibian relative abundance, species richness, and diversity for the remaining phases of this long-term project. A second, broader goal was to examine and model the relationship between habitat characteristics measured across the industrial forest landscape and amphibian relative abundance. Hopefully, my project will provide MeadWestvaco forest managers with amphibian biological and habitat data so they in turn can apply that knowledge to management strategies. Examples of such strategies might include preserving intact forest buffers (mature stands that are left unharvested) and establishing corridors between amphibian breeding sites and mesic habitat (Dr. Patrick D. Keyser, Wildlife Biologist, Westvaco Corporation, pers. comm., 2001).

Project Design

The experimental design divides the WERF into 2 blocks, with 3 forest compartments in each. An additional block with 3 forest compartments is established on MeadWestvaco industrial forest in nearby Cassity, WV, approximately 6.4 km (4 mi) north of the WERF. Forest compartments are non-uniform in shape and range in size from 493 ha (1217 ac) to 539 ha (1331 ac); the average size is approximately 518 ha (1280 ac) or 2 mi^2 (Figure 1.1).

In the future, experimental treatments will be replicated across blocks and will consist of 3 harvest disturbance classes (intensive=20-year rotation, moderate=40-year rotation, and light=80-year rotation). Manipulating harvest intensity will ensure that after 10 years compartments will differ in the percent covered by <10-year age classes (intensive 50%, moderate 25%, light 12%). Each of the 9 forest compartments has been assigned a harvest treatment randomly within a block. Each of the 3 replicate blocks is made of 3 adjacent forest compartments, representing each of the 3 harvest treatments (Figure 1.1). Within a replicate block, compartments are similar in age class distribution, stand type, and site index (Table 1.1).

Clearcut timber harvests will be implemented in each compartment to serve as references. These cuts will have a southeast aspect and will cover approximately 11.2 ha (28 ac). Harvests within the compartments of 1 block will be completed August-December in the same year. Reference areas were chosen to serve as long-term monitoring areas to examine salamander community structure, distribution, and recolonization rates in clearcuts situated in landscapes with different harvest intensities.

Study Site

The MeadWestvaco Corporation, an international, multi-billion-dollar member of the paper products industry, has responded to a growing public demand for sustainable management of natural resources (Kessler et al. 1992, Sharitz et al. 1992, Siegel 1995). MeadWestvaco has set an example for the private timber industry by sponsoring multiple ecosystem research projects on the MeadWestvaco Wildlife and Ecosystem Research Forest (WERF) in Randolph County, in east-central West Virginia. The WERF is the first industrial research forest of its kind in the United States (Keyser et al. 2003a).

Dedicated in 1994, the WERF is devoted to a mission of short-term and long-term research on the effects of commercial silviculture practices on biodiversity and forest ecosystem health. The WERF totals 3,413 ha (8,430 ac) or approximately 13 km^2 in the Allegheny Plateau physiographic province in the central Appalachian Mountains. Two entire watersheds and the upper reaches of a third are contained within its boundaries. Elevation on the WERF ranges from 734 m (2275 ft) to 1180 m (3540 ft). Steep slopes, ridge top plateaus, small, high-gradient streams, and acidic, well-drained soils characterize the WERF landscape. A cool, humid climate allows for yearly precipitation of >160 cm, including ample snow throughout the winter (Keyser et al. 2003b).

Mixed mesophytic and xeric hardwoods dominate the WERF landscape. At higher elevations, yellow birch (*Betula lutea*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*), Fraser magnolia (*Magnolia fraseri*), and American beech (*Fagus grandifolia*) are common species. At lower elevations, communities of cucumber magnolia

(*Magnolia acuminata*), American basswood (*Tilia americana*), yellow poplar (*Liriodendron tulipifera*), black birch (*Betula lenta*), N. red oak (*Quercus rubra*), white oak (*Quercus alba*), and white ash (*Fraxinus americana*) are typical. At the highest elevations, E. hemlock (*Tsuga canadensis*) and red-spruce (*Picea rubens*) forest occurs. Southwestern, xeric slopes at low elevations often have communities of black oak (*Quercus velutina*), chestnut oak (*Quercus prinus*), scarlet oak (*Quercus coccinea*), shagbark hickory (*Carya ovata*), mockernut hickory (*Carya tomentosa*), and pignut hickory (*Carya glabra*). Riparian areas are characterized by rosebay rhododendron (*Rhododendron maximum*), while striped maple (*Acer pennsylvanicum*) and hay-scented fern (*Dennstaedtia punctilobula*) dominate the understory throughout the WERF (Keyser et al. 2003b).

OBJECTIVES

1. Examine relationships between habitat characteristics and terrestrial amphibian relative abundance, species richness, and diversity.

2. Conduct a use/availability analysis on rocks and woody debris to examine salamander preferences for natural cover object characteristics

3. Record presence of aquatic habitats across the landscape

4. Provide preharvest and postharvest data on terrestrial amphibian relative abundance, species richness, diversity, and distribution in clearcut reference areas

5. Use a similarity index to compare 2 sampling techniques (nighttime area-constrained searches and daytime coverboard sampling) in terms of proportions of common species captured

CHAPTER 1

TABLES

Table 1.1. Summary of 2001-2002 study sites showing clearcut reference area compartments, replicate blocks, and harvest treatment blocks, along with timber harvest schedule and stand characteristics, MeadWestvaco industrial forest, Randolph County, WV. Site index (S.I.) is based on N. red oak (*Quercus rubra*) at age 50, and stand age reflects age before harvest; see Chapter 1 "Study Site" or Chapter 3 "Stand Characteristics" for stand type descriptions.

COMP	REP BLOCK	HARVEST SCHEDULE	HARVEST TREATMENT	S.I.	PREHARVEST STAND AGE	MEAN ELEV (ft)	STAND TYPE
1	A	Fall 2003	INTENSIVE (~20-yr rotation)	70	83	2800	MH
2	A	Fall 2003	MODERATE (~40-yr rotation)	68	81	2600	MH
3	A	Fall 2003	LIGHT (~80-yr rotation)	66	82	2600	MH
4	B	Fall 2002	LIGHT (~80-yr rotation)	70	70	2600	UH
5	B	Fall 2002	INTENSIVE (~20-yr rotation)	67	77	3200	MH
6	B	Fall 2002	MODERATE (~40-yr rotation)	75	80	3000	MH
7	C	Fall 2001	MODERATE (~40-yr rotation)	74	75	3400	MH
8	C	Summer 2001	INTENSIVE (~20-yr rotation)	70	80	3000	UH
9	C	Fall 2001	LIGHT (~80-yr rotation)	76	83	3200	MH

CHAPTER 1

FIGURES

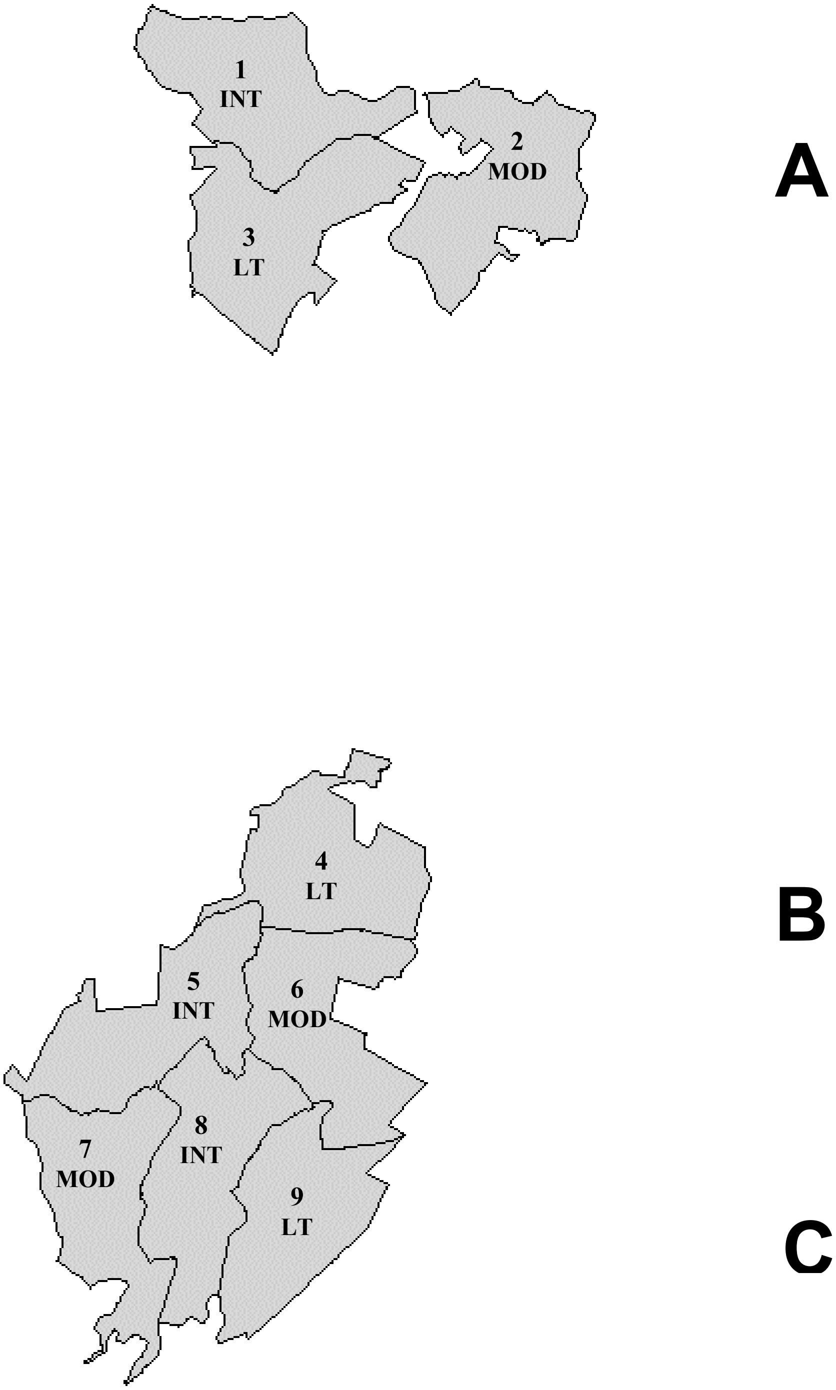

Figure 1.1. Schematic (to scale) showing layout of Appalachian Landscape Ecology Project (ALEP) study sites in Randolph County, WV. Replicate blocks A, B, and C are made of 3 forest compartments each with individual compartments assigned a forest treatment: light (80-yr rotation), moderate (40-yr rotation), or intensive (20-yr rotation); replicate block A (compartments 1-3) is located on MeadWestvaco industrial forest, while replicate block B (compartments 4-6) and replicate block C (compartments 7-9) are located ~6.4 km (~4 mi) south on the MeadWestvaco Wildlife and Ecosystem Research Forest (WERF); compartments are approximately 518 ha each (~2 mi^2).

CHAPTER 2: AMPHIBIAN-HABITAT RELATIONSHIPS ACROSS AN INDUSTRIAL FOREST LANDSCAPE

INTRODUCTION

A long-term landscape ecology project with an amphibian component is timely. The last few decades have witnessed a gradual shift in the focus of conservation and ecology (Zonneveld and Forman 1990, Miller 1996). Except in endangered species cases and traditional game management, it is no longer commonplace to focus exclusively on individual species. Rather, biologists and managers concerned with preserving biodiversity now approach wildlife management from a holistic, landscape, or ecosystem level where multiple taxa and habitats are considered in conservation and management decisions (Meffe and Carroll 1997).

The concept of sustainability in natural resources can be defined as using renewable resources in accordance with their productive limits to meet current needs without compromising the resource's availability or productivity in the future. This idea is the main motivation behind the paradigm shift in natural resource management, particularly in forestry (Forman 1990, Barrett and Bohlen 1991, Sauer 1994). For example, the links between biodiversity and forest succession are well known; managing forests for biodiversity often means creating and maintaining a balance of forest age classes across the landscape (Hunter 1990).

In landscape ecology, scientists and managers consider the spatial and temporal interactions across the landscape mosaic and the influences of spatial heterogeneity on ecological processes and biodiversity (Merriam 1988, Zonneveld 1990, Barrett and Bohlen 1991, Naveh 1994). There is a growing need and demand for long-term, cost-effective research at the ecosystem and landscape levels, especially due to the rapid encroachment of modern development and habitat loss (Barrett and Bohlen 1991, Sauer 1994). Large landowners, such as forest industry, often have the opportunity to manage forests long-term at the landscape scale, but little ecological information is available to inform these decisions.

As important as the landscape level approach to this project are the fauna studied. Pauley et al. (2000) state that understanding herpetofaunal life history dynamics on a landscape scale is primary to developing management plans for these species. Previous studies have looked specifically at landscape level amphibian distribution and habitat disturbance. Pearman (1997) researched correlates of amphibian diversity across a disturbed, tropical landscape in Ecuador, and found that species richness increased as distance to non-forested habitat increased. Gibbs (1998) examined the relationship of life history traits to distribution across a fragmented forest landscape for 5 amphibian species in Connecticut and found that the more mobile species (e.g., *Rana sylvatica* and *Notophthalmus v. viridescens*) were the least tolerant of habitat fragmentation. Finally, Kolozsvary and Swihart (1999) studied landscape level correlations of habitat fragmentation and amphibian distribution across midwestern farmland and discovered that a non-random distribution suggested amphibians were responding to landscape level changes in their environment.

Relationships between amphibians and specific habitat features have been the focus of previous research. Studies have been conducted in the Pacific northwest pertaining to amphibians and tree species, leaf litter depth, natural cover objects, slope, herbaceous vegetation, canopy, and stand age (Block and Morrison 1998; Aubry 2000). Research completed in the forested midwest has examined relationships between amphibians and natural cover objects, canopy cover, ground cover, and herbaceous and woody vegetation (Herbeck and Larsen 1999). In the southeast coastal plain, researchers have studied amphibians in relation to habitat characteristics such as forest type

(Bennett et al. 1980, Hanlin et al. 2000). The majority of studies of habitat in eastern deciduous forests have been in New England or New York (e.g., Pough et al. 1987, DeGraaf and Rudis 1990) despite the wealth of studies of salamander biology in the southern Appalachians; these researchers examined relationships between amphibians and habitat characteristics such as leaf litter depth, slope, aspect, elevation, basal area, ground cover, and canopy cover.

Only a few studies exist that examine direct effects of landscape level disturbance on amphibian populations and communities. As an example of such a study, Gibbs (1998) researched how landscape disturbance in a southern Connecticut forest affected amphibian demographics and genetics. His results suggested that genetic differentiation was greater among amphibian populations found in a fragmented landscape compared with populations in an undisturbed landscape. Gray (2002), in the abstract to his dissertation, also examined how landscape structure and disturbance affected amphibian morphology and demographics. His results indicated that amphibian relative abundance was positively correlated with landscape complexity and that landscape disturbance resulted in a decrease of mean morphological characteristics as well as altered population demographics and community dynamics.

Many researchers have examined amphibian species richness, abundance, and distribution on small and large scales in various settings throughout the United States. However, a landscape level and forest stand level examination of the relationship between amphibians and habitat in a central Appalachian forest is lacking. This study will contribute to the growing body of research on the relationship between silviculture, amphibians, and habitat.

OBJECTIVES

My first objective was to examine relationships between habitat characteristics (micro and stand level) and terrestrial amphibian species richness and relative abundance. My second objective was to conduct a use/availability analysis to assess salamander preferences for characteristics of naturally occurring rock and wood cover objects. My third objective was to record the presence of available aquatic habitats (e.g., ephemeral and permanent streams, ephemeral pools, wetlands, and permanent ponds) across the landscape to begin monitoring how silvicultural activities affect the quantity of these habitats.

METHODS

Terrestrial Sampling

For the first objective, to examine relationships between micro and stand level habitat characteristics and terrestrial amphibian species richness, diversity, and relative abundance, my crew members and I conducted annual surveys over 2 summer field seasons for terrestrial amphibians. In May 2001 and throughout the 2002 season (May-July), we conducted area-constrained searches (Jaeger and Inger 1994) using random-systematic plots located along transects (Jaeger 1994). Transects ran perpendicular to the prevailing topography (e.g., east-west).

We sampled 10 m x 10 m plots, approximately 300 m apart, along transects until we had sampled 4-6 plots per transect (Figure 2.1).

Sampling order of replicate blocks was determined at random. We sampled 1 transect on all 3 compartments within a replicate block in a single day, to control for seasonal and weather-related variation. Transect sampling completed in May 2001 was the only time we were not able to sample within a replicate block on the same day.

In 2002 along with sampling these terrestrial plots, every other SMZ (Stream Management Zone) habitat was sampled regardless of how close previous or subsequent terrestrial plots were placed. Our working definition of a SMZ was a perennial (water present year-round) or ephemeral creek or stream (water present seasonally) or a permanent pool that forest managers might consider buffering from logging activities to protect water quality (Ilhardt et al. 2000, Phillips et al. 2000). Run-off from new clearcuts, rivulets and seeps on skidder trails, wetlands, and low-lying bottomland ephemeral pools or wet areas that were sometimes in or near terrestrial plots were not considered SMZs. Crews sampled the first SMZ they encountered and then every other one from that point forward. SMZ plots were established directly adjacent to the stream bank with plot edges at the water/land interface but not including the stream itself (Figure 2.1).

From 21-29 May 2001, we sampled 4 transects with 19 plots in 3 forest compartments using these methods. Six of the 19 plots (32%) were located in SMZs. From 27 May-31 July 2002, we sampled 45 transects with 219 plots across 9 forest compartments (24-25 plots per compartment) using these same methods; 66 of the 219 plots (30%) were located in SMZs.

Methods used to select the plots sampled from 30 May through 31 July 2001 differed from those used prior to that date and those used during the entire 2002 field season. During this time in 2001, we sampled 132 plots in the 6 forest compartments on the WERF; 52 of the 132 plots (39%) were located in SMZs. Instead of sampling transects with random-systematic plots, we followed protocol used by other projects studying the songbird (West Virginia University) and vegetation (Clemson University) components of the ALEP. Permanent plots, systematic-randomly located in the mid-1990s for forest census objectives, were used to place 90 of our 132 plots, 10 of which (11%) were located in SMZs. To supplement upland or mesic terrestrial plots, we sampled 7 additional riparian plots on each of the 6 WERF forest compartments. We chose SMZs along perennial and intermittent streams based on their easy access from forest roads.

To sample all plots, we used an area-constrained search technique (Jaeger and Inger 1994). With this technique we flipped over cover objects such as logs and branches (at least 5 cm wide), other woody debris (e.g., movable stumps), and rocks (at least 8 cm long) to find amphibians underneath. Two people lifted objects too large or heavy for one person to lift. If objects were too heavy or cumbersome to move (e.g., wider than 0.75 m or longer than 5 m), they were not sampled. Cover objects that fell on the north (top) and west (left) plot boundaries were included in the sampling effort; those that lay on the south (bottom) and east (right) boundaries were not included. Logs and other objects were replaced before leaving the area, and any captured animals were released next to the replaced cover object under which they were found. Rock outcrops that fell within our plots were sampled for green salamanders (*Aneides aeneus*) by shining a flashlight into cracks and crevices on the rock face (Pauley and Rogers 1998). (We did not succeed in finding green salamanders in rock outcrops, so no results will be presented for this technique.)

Population Characteristics

When we caught amphibians, we temporarily placed them in labeled zipper-locking plastic bags. Labeled pin flags marked the exact location of capture for reference so animals could be returned after processing. For each captured amphibian, we measured snout-vent length (SVL) and total length (TL) to the nearest 0.1 mm (Fellers et al. 1994, Harpole 1996, Knapp 1999). Individuals were weighed to the nearest 0.01 g. We determined the sex of amphibians by observing secondary sex characteristics and/or by using a concentrated beam from a Mini-MagLite^{TM} flashlight. For light-bodied salamanders, shining the light through their body allowed us to see and count the approximate number of eggs in gravid females or see the presence of pigmented testes in males (Harpole 1996, Knapp 1999). When possible, at least 2 different crew members, counted yolked eggs to reach a consensus on the minimum number present. Other physical characteristics, such as a missing or regenerating tail, or abnormalities, such as a missing limb or a deformation, were also recorded.

Habitat Characteristics

Before captured animals were returned to their spot of capture and displaced cover objects were restored, we measured various microhabitat and stand level habitat characteristics. These characteristics are described below and listed by year in Table 2.1.

Ground and Midstory Canopy Cover

For 2001 and 2002 we recorded ocular estimates from the center of plots for % cover of bare ground, rocks, woody debris, herbaceous vegetation, and woody stems ($\leq$7.5 cm DBH). Estimates were based on cover classes: 0=<5%, 1=5-25%, 2=26-50%, 3=51-75%, 4=76-95%, 5=>95% (Daubenmire 1959, Harpole 1996, Knapp 1999). In 2001we recorded % cover of herbaceous vegetation and woody stems on transects in May and on the riparian plots we chose but not on plots at the permanent forest markers. Our intention was to use data for these characteristics Clemson University researchers collected at the permanent forest markers.

Basal Area

In 2001 only, we used a ruler to measure DBH (diameter at breast height) of overstory trees ($\geq$7.5 cm DBH), identified to species, within plot boundaries. We then used those data to calculate the basal area (m^2/ha) for each plot. Tree species data were collected but not used in any analyses.

Overstory Tree Density

In 2002 only, we tallied the number of overstory trees by species present within each plot. Overstory trees counted included those >7.5 cm DBH.

% Canopy Cover

In 2001 we obtained an index of % canopy cover from the center of each plot with ocular estimates but did not assign these to cover classes. We used a tube pointed directly overhead to estimate % canopy cover. In 2002 we recorded % canopy in 4 cardinal directions using a spherical densiometer. One crew member stood in the center of each plot and rotated to the north, south, east, and west, recording % canopy in each direction. We used these 4 readings to calculate an average for the whole plot.

Leaf Litter Measurements

In 2001 and 2002 we dug a soil profile in 3 random locations within each plot. We used a ruler to measure the surface leaf litter layer depth (cm) (DeGraaf and Rudis 1990, DeGraaf and Yamasaki 2002). In 2002 we also collected all surface leaf litter within a $0.25 m^2$ PVC pipe frame placed in 3 random locations. We recorded a wet biomass, dried samples for at least 48 hours in a laboratory drying oven at 65^o C, and recorded a dry biomass (Harpole 1996, Knapp 1999). We calculated % moisture for each sample based on the difference in wet and dry biomass.

Soil Measurements

In 2001 we measured the soil organic layer depth (cm), or the "O" horizon, in the same soil profiles used to measure leaf litter depth; we did not measure this soil characteristic in 2002. In 2002 in 2 random locations per plot, we used a soil corer (5 cm diameter) to extract a soil sample from the surface to 10 cm in depth. We placed samples in labeled plastic soil bags to use in laboratory soil pH analyses using gravimetric methods. We created 1:1 soil-water solutions (e.g., 20 ml soil and 20 ml distilled water) and used a laboratory pH meter (calibrated with buffers of pH 4 and 7) to measure soil pH (USDA 1996).

Distance to Water

In 2001 and 2002 we characterized each plot as SMZ or non-SMZ based on the distance to perennial or intermittent streams and permanent pools. Plots had to be within 15 m from these aquatic habitats to be counted as a SMZ. I chose the 15 m buffer because plots within this distance would always fall within Best Management Practices (BMP) buffer recommendations for silvicultural operations in West Virginia and because that distance was relatively easy to estimate visually in the forest. Several plots were adjacent to or contained seeps or ephemeral pools but were not considered SMZs because they did not meet the criteria that would require streamside management practices. A defined SMZ consists of a stream and adjoining riparian area of varying widths where timber management practices must be modified and closely monitored to avoid potential negative effects on water quality or aquatic habitat (Phillips et al. 2000).

Stand Characteristics

For 2001 and 2002 we obtained stand ages, stand types, and site index values by using the GPS locations we recorded at each plot and available GIS data provided by MeadWestvaco. Site index values are measures of potential site productivity or the average height (ft) that a tree species could grow in 50 years. Site index on MeadWestvaco forest is based on northern red oak (*Quercus rubra*). I treated stand age and site index as continuous data since it was unclear how to break these data into distinct classes. Stand types were mountain hardwood, cove hardwood, upland hardwood, or open/non-forest. Mountain hardwoods were characterized by species such as black cherry (*Prunus serotina*), N. red oak, sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), yellow birch (*Betula lutea*), and Fraser magnolia (*Magnolia fraseri*). Cove hardwood stands were the moistest, richest sites, characterized by tulip poplar (*Liriodendron tulipifera*), basswood (*Tilia americana*), sugar maple, cucumber magnolia (*Magnolia acuminata*), American beech (*Fagus grandifolia*), sweet birch (*Betula lenta*), white ash (*Fraxinus americana*), and N. red oak. Representative species of upland hardwood stands, the driest type, included N. red oak, chestnut oak (*Quercus prinus*), white oak (*Quercus alba*), scarlet oak (*Quercus coccinea*), hickories (*Carya* spp.), red maple, and blackgum (*Nyssa sylvatica*). Finally, nonforest or open areas included gas and powerline right-of-ways, roads, areas around gas wells, and strip mine reclamation areas (Dr. Patrick D. Keyser, Forestry Division, MeadWestvaco Corp., pers. comm., 2003).

Cover Object Use/Availability

For the second objective, to conduct cover object use/availability analyses to examine salamander preferences for natural cover object characteristics, in 2001 and 2002 we stretched a meter tape diagonally across plots to count all available rock and wood cover objects. Using line-intercept methods, we recorded data on each object that fell on the tape. For wood cover objects we used the woody debris decomposition class system of Maser et al. (1979) to tally the total number in each class (1-5, 1=newly fallen log, 5=highest level of decomposition). We measured the length (cm) and width (cm) of each wood cover object and measured the length (cm) of each rock. In 2002 we also recorded the shape of each rock (e.g., flat vs. all other shapes) and used the measured lengths and shapes to classify each rock type (e.g., cobble, channer, flagstone, stone, and boulder) (USDA 1998). These same data were collected for each used wood and rock cover object under which an amphibian was found during our surveys. Rocks and woody debris that were too heavy or cumbersome to move (e.g., wider than 0.75 m or longer than 5 m), were counted as available but were not sampled. However, only a few objects encountered were not possible for us to lift. Less than 1-2% of all objects were not sampled.

Aquatic Habitats Encountered

To meet the third objective, to record the presence of available aquatic habitats (e.g., ephemeral and permanent streams, permanent ponds, ephemeral pools, wetlands, and skid trail seeps and ruts holding water) across the landscape, crews identified and kept a tally of all aquatic habitats encountered on transects. Crews used a GPS unit to collect UTMs for each habitat encountered while hiking transects. When crews were unable to obtain a GPS reading within a reasonable amount of time (e.g., 5 minutes), they recorded written notes describing the location and approximate distance paced from the previous plot.

STATISTICAL ANALYSES

My goal was to study amphibian-habitat relationships across the landscape, so I did not analyze differences in amphibian population or community metrics across compartments. These types of analyses will be described in Chapter 3. I used either SAS (SAS Institute 2002) or JMP (SAS Institute 2001) statistical software and a significance level of 0.10 for all analyses.

Relative Abundance, Species Richness, and Species Diversity

I used a Student's t-test to examine differences in relative abundance between years and differences in relative abundance observed between SMZ and non-SMZ plots, on a per plot basis to correct for the unequal number of SMZ and non-SMZ plots, for the most common species captured and processed. I calculated Simpson's index of diversity (Krebs 1999), a measure of species dominance, to analyze community composition across all plots combined, across SMZ plots only, and across non-SMZ plots only. Simpson's index can range from 0 to 1 (1=highest level of diversity possible) and is interpreted as the probability that 2 individuals picked at random will be from different species.

Population Characteristics

Population demographics, sex ratio, and age class distribution were summarized for all 10 m x 10 m terrestrial plots for each year. I have presented the proportions of gravid females and individuals with missing or regenerating tails and summarized our observations of salamander clutches found under cover objects or leaf litter. Minimum SVLs used to classify adults and juveniles were based on published data from the Appalachian region (Petranka 1998) and on my own field observations of minimum sizes of gravid females. I used the following minimum SVLs by species: redback salamander (*Plethodon* c*inereus*) males=32 mm, females=34 mm; slimy salamander (*Plethodon g. glutinosus*) males=45 mm, females=58 mm; Wehrle's salamander (*Plethodon wehrlei*) adults=61 mm; N. two-lined salamander (*Eurycea b. bislineata*) adults=35 mm; Allegheny Mt. dusky salamander (*Desmognathus ochropheus*) adults=30 mm; N. dusky salamander (*Desmognathus f. fuscus*) adults=30 mm; Appalachian seal salamander (*Desmognathus m. monticola*) adults=34 mm; and four-toed salamander (*Hemidactylum scutatum*) adults=29 mm. For N. spring salamander (*Gyrinophilus p. porphyriticus*) adults, I used TL=110 mm as recommended by Petranka (1998).

Habitat Characteristics

Habitat characteristics to be sampled were chosen *a priori* based on literature searches of similar studies and on published information of habitat qualities important for amphibians. For each year, where applicable, I have summarized mean values of continuous habitat variables and % frequencies of categorical habitat variables. For 2001 leaf litter and soil organic layer depths and for 2002 leaf litter depth and leaf litter biomass, I calculated the coefficient of variation (C.V.) between the 3 replicated measures of depth and biomass to demonstrate effects the mountainous terrain had on these data (e.g., more leaf litter and organic soil accumulation at toe slopes than side slopes) which could affect their significance in habitat models.

Amphibian-Habitat Relationships

I performed a square-root transformation on capture data for each year to decrease variance caused by high capture rates on a few plots (e.g., >20 captures) and 0 captures on others. I plotted the distribution of transformed capture data to ensure statistical assumptions of normality were met. After performing the transformation, I evaluated habitat variables for multicollinearity and used stepwise procedures with a significance level of 0.10 in multiple linear regression analysis to develop models predicting amphibian relative abundance for all species combined. I examined residual plots of habitat variables to ensure all statistical assumptions were met.

Variables used in regression analyses for 2001are listed in Table 2.1. In 2001 % canopy cover and % herbaceous vegetation were not included in the analysis for all plots and for non-SMZ plots because fewer than 50% of plots sampled had these data. It was intended that the Clemson University vegetation study would provide these data, but it was discovered after the field season that their methods and ours were not similar enough. For SMZ plots, we did include % canopy cover and % herbaceous vegetation since these plots were not located at the permanent forest stakes and we collected all the data. We estimated the percent cover of rocks in each plot and counted available rocks along diagonal transects in plots. However, I used the count of rocks along transects in all regression analyses instead of % rock cover.

Cover Object Use/Availability

With each year's data I performed compositional analyses in SAS (SAS Institute 2002) to examine preferences between wood and rock cover objects on all terrestrial plots, on SMZ plots only, and on non-SMZ plots only. For all 2001 and 2002 plots where woody debris was used, I performed compositional analyses to examine preferences among lower levels of woody debris decomposition (classes 1-2) and higher levels of woody debris decomposition (classes 3-5) (Maser et al. 1979). I also analyzed preferences in wood width (cm) classes and length (cm) classes. For all 2001 plots where rocks were used, I examined preferences among rock length (cm) classes. For all 2002 plots where rocks were used, I analyzed preferences among rock shape classes and rock type classes based on shape and length (cm) measurements (USDA 1998).

Aquatic Habitats Encountered

Due to the methods used in 2001 terrestrial sampling (i.e., establishing plots at permanent forest markers), no aquatic habitat data are available for that year. For 2002 only, I summarized our observations and reported the total number and types of aquatic habitats we encountered while hiking across the landscape.

RESULTS

Relative Abundance, Species Richness, and Species Diversity

From 21 May to 31 July 2001, we captured and/or observed a total of 12 amphibian species across 151 terrestrial 10 m x 10 m plots, including 2 anuran species (represented by 2 individuals) and 10 salamander species. From 27 May to 31 July 2002, we captured and/or observed 14 amphibian species, including 4 anuran species (represented by 7 individuals) and 10 salamander species across 219 plots (Table 2.2, Appendix A). Although we sampled 68 fewer plots in 2001 than in 2002, we captured 269 more amphibians in 2001.

Including escaped, unprocessed individuals, we observed 821 amphibians (mean per plot=5.44 ±0.413) in 2001 on 151 plots and 552 amphibians (mean per plot=2.52 ±0.278) in 2002 on 219 plots. A Student's t-test showed a significant difference in relative abundance across years (t=7.42, df=368, p<0.0001) (Table 2.3). For both years, relative abundance was higher on SMZ plots (2001: mean=8.41±0.792, n=58 plots; 2002: mean=5.11±0.733, n=66 plots) than non-SMZ plots (2001: mean=3.58 ±0.335, n=93 plots; 2002: mean=1.39±0.177, n=153 plots). Overall, we did not observe amphibians on 9% (n=14) of all 2001 plots sampled and on 37% (n=82) of all 2002 plots sampled. Of all 2001 non-SMZ plots, we found no amphibians on 14% (n=13) of the plots, while only 2% (n=1) of all SMZ plots had no amphibians. Of all 2002 non-SMZ plots, we found no amphibians on 50% (n=77) of the plots, while 12% (n=8) of all SMZ plots had no amphibians. The most captures in a single sampling event both years occurred on a SMZ plot (2001: n=27, 2002: n=41). Student's t-tests showed a significant difference in relative abundance between SMZ plots and non-SMZ plots for 2001 (t=-6.61, df=149, p<0.0001) and for 2002 (t=-7.83, df=217, p<0.0001) (Table 2.3).

We observed more amphibian species in SMZ habitats than in non-SMZ habitats and discovered differences in salamander community diversity between the 2 habitat types (Table 2.4). For both years as expected, the riparian community on SMZ plots was predominantly made of semi-aquatic species of the genera *Desmognathus*, *Eurycea*, and *Gyrinophilus* such as Appalachian seal (*D. m. monticola*), Allegheny Mt. dusky (*D. ochropheus*), N. dusky (*D. f. fuscus*), N. two-lined (*E. b. bislineata*), and N. spring salamanders (*G. p. porphyriticus*). As mentioned previously, seeps, wet areas, and/or ephemeral pools were contained in or found adjacent to some terrestrial plots that were classified as non-SMZ, which explains why these species were sometimes captured away from a perennial or ephemeral streams.

A Student's t-test completed for each of the most common species revealed significant differences in relative abundance between 2001 SMZ and non-SMZ habitat for 4 out of 6 species: N. dusky (t=-6.80, df=149, p<0.0001), Allegheny Mt. dusky (t=-5.90, df=149, p<0.0001), Appalachian seal (t=-5.97, df=149, p<0.0001), and N. two-lined salamanders (t=-4.73, df=149, p<0.0001). No significant differences were detected for redback (t=0.80, df=149, p=0.4225) or slimy salamanders (t=-0.08, df=149, p=0.9365) in 2001(Table 2.5) (Figure 2.2). In 2002, the same 4 species showed significant differences in relative abundance between SMZ and non-SMZ habitat: N. dusky (t= -6.09, df=217, p<0.0001), Allegheny Mt. dusky (t=-8.64, df=217, p<0.0001), Appalachian seal (t=-5.92, df=217, p<0.0001), and N. two-lined salamanders (t=-2.16, df=217, p=0.0320). Redback (t=-1.29, df=217, p=0.1999) and slimy salamanders (t=-1.12, df=217, p=0.2636) did not show significant differences between the 2 habitat types (Table 2.5) (Figure 2.2).

To examine community diversity in these habitats, I used Simpson's index of diversity (Krebs 1999) to discover that diversity was slightly higher on SMZ plots vs. non-SMZ plots in 2001 and slightly lower on SMZ plots vs. non-SMZ plots in 2002. For all plots combined, diversity was lower in 2002 than in 2001 (Table 2.6).

Population Characteristics

Morphological Characteristics

Measurements of morphological characteristics were similar to those Petranka (1998) reported for the Appalachian Mountain region for all species except N. dusky salamander and Appalachian seal salamander. In both cases, we measured adults (determined by presence of pigmented testes or yolked eggs) that were 30 mm SVL, 2-4 mm smaller than the minimum size Petranka (1998) reported for these 2 species (Tables 2.7-2.8).

Sex Ratio and Age Class Distribution

For 2001, the sex ratio was slightly skewed in favor of males for Appalachian seal salamanders, skewed in favor of females for N. dusky salamanders, and approximately equal for Allegheny Mt. dusky and redback salamanders. Juveniles outnumbered adults for slimy salamanders and redback salamanders. For all other species analyzed, juveniles were less numerous than adults with ratios ranging from approximately 1:2 to 1:4, juveniles to adults (Table 2.9).

In 2002, the adult sex ratio was greatly skewed in favor of females for Appalachian seal, redback, and slimy salamanders. The sex ratio was approximately equal for N. dusky salamanders and was skewed in favor of males for Allegheny Mt. dusky salamanders. Juvenile N. two-lined salamanders and slimy salamanders outnumbered adults of those species. For all other species analyzed, juveniles were less numerous than adults with ratios ranging from approximately 1:2 to 1:5, juveniles to adults (Table 2.9).

Fertility and Fecundity

Out of 175 light-bodied female salamanders captured and processed in 2001, 22 were gravid (13%); 15 out of 126 (12%) were gravid in 2002 (Table 2.10). We discovered a total of 14 clutches in 2001 and 10 clutches in 2002 in nests under cover objects or under disturbed leaf litter. In 2001, 7 clutches were unattended, and 7 had brooding females guarding the nests (6 redback salamanders, 1 N. dusky salamander). In 2002, 3 clutches were unattended, and 7 had brooding females present (6 redback salamanders, 1 four-toed salamander). The mean clutch size counted in redback salamander nests in 2001 was 8.6 eggs (min=4, max=19); a count of eggs in the N. dusky salamander nest was not recorded. Mean clutch size in redback salamander nests in 2002 was 6.5 eggs (min=5, max=8), while the four-toed salamander nest had 14 eggs.

Regenerating Tails

Eighty out of 741 (11%) captured and processed salamanders in 2001 and 12 out of 416 (3%) captured and processed salamanders in 2002 had missing or regenerating tails. In 2001, 42 salamanders were in SMZ habitats (0.72 per plot, n=58 plots), while 38 were in non-SMZ habitats (0.41 per plot, n=93 plots). In 2002, 5 salamanders were in SMZ habitats (0.10 per plot, n=66 plots), and 7 were in non-SMZ habitats (0.05 per plot, n=153 plots). A summary of % captured and processed individuals that had regenerating or missing tails by species and sex is displayed in Appendix B. Chi-square analyses showed no significant differences between the number of individuals with missing or regenerating tails in SMZ habitats vs. non-SMZ habitats in 2001 (X^2=1.062, df=739, p=0.3028) or in 2002 (X^2=1.614, df=414, p=0.2040) (Table 2.11).

Habitat Characteristics

Out of 151 plots sampled in 2001, 58 (38%) were located in a SMZ, while 93 (62%) were located in non-SMZ habitat. In 2002, out of 219 plots sampled, 66 (30%) were in a SMZ, and 153 (70%) were classified as non-SMZ.

Of the 4 stand types sampled in 2001 and 2002 (e.g., open/nonforest, mountain hardwood, cove hardwood, and upland hardwood), mountain hardwood was the most common stand type sampled both years and the most common stand type occurring on the study areas (Table 2.12). For % cover classes of ground and mid-story habitat characteristics, no variable had >95% total plot coverage either year, and all peaked in the <5% or 5-25% ranges (Table 2.13).

Continuous habitat data showed that the majority of 2001 terrestrial plots were in mature forest (mean stand age=72 yrs), with a high site index (mean=72), relatively dense canopy cover (mean=75%) and basal area (mean=26 m^2/ha), with well-decomposed available woody debris (mean=5.81 pieces of decomposition class 3-5 woody debris) and several available rock cover objects (mean=3.5 rocks) along diagonal transects, and with well-established leaf litter (5.67cm) and organic soil layers (13.50 cm) (Table 2.14). Similar to 2001, continuous habitat data for 2002 revealed, in general, that 2002 terrestrial plots were in mature forest (mean stand age=70 yrs), with a relatively high site index (mean=70), dense canopy cover (mean=84 %), with well-decomposed available woody debris (mean=3.3 pieces of decomposition class 3-5 woody debris) and several available rock cover objects (mean=3.7 rocks) along diagonal transects, with relatively low soil pH (mean=4.1), and with a well-established leaf litter layer (mean biomass=25.6 g/0.25m^2) (Table 2.14).

Amphibian-Habitat Relationships

<u>All Plots</u>

Stepwise multiple linear regression procedures for all 2001 terrestrial plots resulted in 3 habitat variables significant at the 0.10 level to predict amphibian relative abundance: SMZ vs. non-SMZ classification, site index, and a count of available rocks along diagonal transects ($p<0.0001$, $F=13.97$, $df=88$). For all 2002 terrestrial plots, 6 variables were significant after stepwise procedures: SMZ vs. non-SMZ classification, soil pH, % canopy, a count of available rocks along diagonal transects, % woody stems (≤ 7.5 cm DBH), and a count of available woody debris along diagonal transects (decomposition classes 3-5) ($p<0.0001$, $F=17.50$, $df=198$). For all 2001 and 2002 terrestrial plots combined, 4 variables were significant after stepwise procedures: SMZ vs. non-SMZ classification, year, a count of available rocks along diagonal transects, and site index ($p=<0.0001$, $F=50.18$, $df=304$). All variables showed a positive relationship with increasing relative abundance except for % woody stems and year (Tables 2.15-2.16).

<u>SMZ Plots</u>

For all 2001 SMZ plots, stepwise procedures revealed 2 habitat variables significant at the 0.10 level to predict relative abundance: site index and % herbaceous vegetation ($p=0.0022$, $F=7.18$, $df=40$). For all 2002 SMZ plots, 3 variables were significant variables for the 2002 model: a count of available rocks along diagonal transects, soil pH, and % canopy cover ($p=<0.0001$, $F=8.82$, $df=59$). Variables significant for all 2001 and 2002 SMZ plots combined included: year and a count of available rocks along diagonal transects ($p=0.0004$, $F=13.52$, $df=106$). All variables had a positive relationship with increasing relative abundance with the exception of year (Tables 2.15-2.16).

Non-SMZ Plots

For all non-SMZ plots in 2001, stepwise procedures resulted in 2 habitat variables significant at the 0.10 level to predict relative abundance: a count of available rocks along diagonal transects and site index (p=0.0019, F=7.35, df=41). Three variables were significant for all 2002 non-SMZ plots: % canopy cover, % woody stems ($\leq$7.5 cm DBH), and a count of available woody debris on diagonal transects (decomposition classes 3-5) (p=0.0003, F=6.74, df=138). Variables significant for all 2001 and 2002 non-SMZ plots combined included: year, a count of available rocks along diagonal transects, % woody stems ($\leq$7.5 cm DBH), and site index (p=<0.0001, F=15.12, df=190). All variables had a positive relationship with increasing relative abundance with the exception of % woody stems and year (Tables 2.15-2.16).

Summary

Of these 9 models, SMZ classification, site index, and a count of available rocks along diagonal transects were the best predictors (based on their partial R^2 values) of amphibian relative abundance out of all habitat variables, explaining the majority of inherent variation in each model. Year was also highly influential in demonstrating an effect on relative abundance from 2001 to 2002. The combined model of both 2001 and 2002 data had the highest R^2_{PRESS} of 0.35. The R^2_{PRESS} statistic reflects the ability of a model to predict actual values (SAS Institute 2000) (Table 2.16).

Cover Object Use/Availability

Rock vs. Wood

In 2001 more wood than rocks was available on all plots, but salamanders used rocks equally or more often than wood on all plots and on non-SMZ plots only. In 2002 more wood was available than rocks on all plots, but salamanders used rocks more often in all cases (Table 2.17). Compositional analyses (SAS 2002) for both years individually (all plots, SMZ plots only, and non-SMZ plots only), where $\geq$1 cover object was used and where cover object data were collected, showed salamanders preferred rocks over wood both years, in all cases except one. The exception occurred in 2001 on SMZ plots; in these plots salamanders did not show a significant preference for rocks or wood (Table 2.18).

Rock Characteristics

The most abundant available rock length (cm) classes across all 2001 terrestrial plots were 11-20 cm and 21-30 cm (Table 2.19). A compositional analysis (SAS 2002) for 2001 showed salamanders preferred rocks that were 31-40 cm long (Table 2.20).

In 2002, flat rocks were the most abundant and most preferred of all shapes of available rocks (USDA 1998). Channers, cobbles, flagstones, and stones were equally available as cover objects in 2002 and the types used most often across all terrestrial plots; salamanders showed the most preference for flagstones over all other types (SAS 2002) (Tables 2.21-2.22).

Woody Debris Characteristics

In 2001 and 2002, woody debris of decomposition classes 3-5 (Maser et al. 1979) was more abundant and was used more often than woody debris of decomposition classes 1-2 across all terrestrial plots (Table 2.23). A multivariate compositional analysis (SAS 2002) showed that salamanders preferred decomposition classes 3-5 woody debris in 2001 and in 2002, indicating a preference for wood that is in a higher state of decay (Table 2.24).

In 2001 and 2002 the most common width of available woody debris was 5-10 cm, followed by 11-20 cm and >20 cm. Woody debris that was 5-10 cm wide was used more often across all 2001 and 2002 terrestrial plots (Table 2.25). In 2001 salamanders showed a slight preference for wood in the 5-10 cm width class but showed no preferences for wood width in 2002 (SAS 2002) (Table 2.26).

Three woody debris length classes substantially outnumbered all others in available woody debris across all 2001 terrestrial plots: ≤50 cm, 51-100 cm, and >300 cm; the most abundant length classes in 2002 were 51-100 cm and >300 cm. The length classes used most often in 2001 and 2002 were 51-100 cm and ≤50 cm (Table 2.27). From results of compositional analyses (SAS 2002), salamanders preferred the ≤50 cm length class and avoided the >300 cm length class in 2001. In 2002 the >300 cm length class was avoided, and although the 201-250 cm length class was the most preferred compared to the other classes, no strong preferences were shown for wood length in 2002 (Table 2.28).

Aquatic Habitats Encountered

In 2002 a total of 141 aquatic habitats was encountered and recorded along transects while crews hiked between terrestrial plots. Habitats were classified into 3 broad categories: pools, wet areas (e.g., wetlands, seeps, bogs, etc.), and streams. Dry, established streambeds with rocky substrate were included in the count (n=12), as were predominantly dry streams or those with interrupted flow (n=8); dry ephemeral pool basins or depressions were not counted because they were difficult to detect. Streams were the most common aquatic habitat type seen (n=95); 66 or 68% were sampled as SMZ plots. Wet areas were the next most common (n=40); none were sampled as SMZ plots. Pools and ponds were the third most common (n=6); 1 or 17% was sampled as an SMZ plot. Finally, at least 23 aquatic habitats were recorded on skidder trails (16%), none of which were sampled as SMZ plots. The mean number of aquatic habitats encountered per transect was 3.13 (n=45 transects) or approximately 1 habitat every 400 m for an average transect length of 1250 m. Appendix C contains a list of GPS locations for aquatic habitats encountered along transects, including those sampled as SMZ plots. Although all aquatic habitats were noted, not all locations were recorded with a GPS unit.

DISCUSSION

Relative Abundance, Species Richness, and Species Diversity

Sampling a total of 370 10 m x 10 m plots (124 SMZ plots, 246 non-SMZ plots) over 2 years across an industrial forest landscape revealed significant differences in relative abundance, similarities in species richness, and slight differences in species diversity. We encountered 14 amphibian species in 2002 and 12 in 2001, but Simpson's index (Krebs 1999) revealed a higher level of diversity for all plots combined and for SMZ plots only for 2001 (all=0.80, SMZ=0.79) vs. 2002 (all=0.74, SMZ=0.68). Non-SMZ plots in both years had a similar level of diversity (0.73 for 2001 and 0.72 for 2002). For both years, as expected, the majority of salamander species composing the SMZ community were *Desmognathus* species and others such as N. two-lined salamander and N. spring salamander whose life history strategies require them to use habitat in and around aquatic sources (Petranka 1998). For non-SMZ habitat, as expected, the majority of salamanders composing this community were *Plethodon* species and other upland species such as N. red-spotted newt (red eft) whose life history strategies allow them to use habitats that are farther from open water (Petranka 1998).

We sampled fewer plots in 2001 than in 2002 but captured and/or observed more amphibians in 2001 than in 2002. We captured approximately 30% more amphibians in 2001, and mean captures per plot was double the rate for 2002. One obvious reason for this discrepancy could be the cumulative effects and increased severity of the prolonged drought in the mid-Atlantic region of the United States. By the middle of 2002, this region of the country experienced the third year in a row of less than normal yearly precipitation (Rekenthaler 1999, USDA et al. 2002, USGS 2002). Climatological data for Randolph County, WV, showed that yearly precipitation totals were 8.52 inches below normal for 1999, 0.40 inches below normal for 2000, and 5.23 inches below normal for 2001; precipitation deficit totals for 2002 were not available due to 1-9 missing days of data in April and December 2002 (NOAA 1999, 2000, 2001, 2002). Comparing rainfall totals in Randolph County, WV, across years for each month we sampled, I discovered that more rain fell in 2001 than in 2002 during our sampling seasons. May 2001 had 5.75 inches of rainfall, while May 2002 had 5.55 inches, June 2001 had 4.98 inches, while June 2002 only had 3.25 inches (1.36 inches below normal), and July 2001 had 8.78 inches, while July 2002 had 7.37 inches (NOAA 2001, 2002).

Lungless salamanders (plethodontids) that require moisture to respire surely felt the cumulative effects of the prolonged drought by 2002. Dry microclimates could have forced these salamanders to seek refuge underground for longer periods of time until conditions improved (Heatwole 1960, Heatwole and Lim 1961, Heatwole 1962, Jaeger 1971, Feder 1983).

Another explanation for the variance in relative abundance between the years could be the difference in crew sizes each year. In 2001 crews always consisted of a minimum of 3 people and often as many as 5 or 6 people, all searching a 10 m x 10 m plot, flipping over cover objects. With this many people in one plot, the likelihood of amphibians escaping without notice or simply being overlooked was less than it was in 2002 when crews consisted of 2 people, and occasionally 3 people. With fewer people searching in 2002, albeit for a longer time, it is possible that on some plots, individual amphibians went undetected, particularly when plots fell in marginal habitat (e.g., recent clearcuts) or habitat that was difficult to negotiate (e.g., briar patches, rhododendron thickets, extreme slopes and hills, etc.). In these areas, having more people to search under slash and through briars, for example, increased the chances of observing salamanders either under objects or escaping across the surface.

Population Characteristics

There were substantial differences observed in sex ratio and age class distribution between 2001 and 2002. Generally, we captured more adults than juveniles and more females than males in our second year of sampling. One reason for the differences between the years could again be the poorer microclimate and microhabitat conditions in 2002 as a result of the prolonged drought. Reproductive rates could have decreased severely in 2001, for species requiring 2 years to yolk eggs, in part because of severe drought conditions in 1999 (8.52 inches below normal yearly precipitation) (NOAA 1999). Conditions in 2000 were less harsh with precipitation 0.40 inches below normal, but the cumulative effect of approximately 3.5 years of drought could have affected reproduction in 2002 (NOAA 2000). Fewer adults, particularly females, engaged in reproductive activities such as brooding clutches, could mean that the likelihood of our seeing adults was greater.

We might have also observed more adults in 2002 because adult salamanders, being larger and more experienced, are better able to find and defend cover objects that might offer refuge from hot, dry conditions than juvenile salamanders. Adults are also better equipped to tolerate poorer microclimate conditions than juveniles or hatchlings and would be more likely to spend more time than juveniles out of underground burrows (Spotila 1972, Mathis 1989, Mathis 1990, Jaeger and Forester 1993, Gabor 1995).

Since we conducted our sampling during the brooding and nesting season for females of most species encountered, I expected to find more adult males than females in our searches. Overall, this assumption held true in 2001. However, in 2002, the sex ratio was skewed in favor of females for species whose females should be nesting and brooding their clutches during our sampling season. For example, redback salamanders, slimy salamanders, and Appalachian seal salamanders usually nest in late June through the summer, which should mean that fewer females would be active on the surface or defending territory under cover objects during these months (Petranka 1998). In 2002 we identified more females than males for these species which could mean that fewer females were engaged in nesting and brooding behavior that year possibly due to poorer microclimate and microhabitat conditions or possibly that females were more likely to risk foraging on the surface in poor conditions to permit future reproduction.

There were slight differences between 2001 and 2002 observations of fertility and fecundity of gravid females. More nests were discovered in 2001 than in 2002. We found 14 nests, or 0.09 per plot, in 2001 and 10 nests, or 0.05 per plot, in 2002; each year we observed 7 females brooding nests. In 2001 and in 2002 only 12% of adult females of light-bodied salamander species were identified as gravid. These percentages fall well below the expected 30-40% range, based on previous work at this site (Knapp 1999), for all species that nested during our sampling season. Again, the 4-year drought could have negatively affected fertility rates. However, another possible explanation again could point to our use of a field transillumination technique that was inadequate to detect the presence of yolked eggs in gravid females, particularly in the redback salamander who ventral side has varying degrees of mottling or peppering of dark spots.

Data on regenerating tails revealed no distinct evidence that the proportion of individuals with missing or regenerating tails differed between SMZ habitat vs. non-SMZ habitat. This phenomenon could indicate that competition or attempted predation existed in equal amounts in both kinds of habitat. Fewer individuals (3%) were identified with regenerating tails in 2002 than in 2001, which, again, is not what would be expected if conditions in 2002 were poorer and thus competition for territories greater. As expected, more adults than juveniles had regenerating tails in 2001 indicating the greater likelihood of adults to participate in aggressive territorial encounters (Mathis 1990, Gabor 1995, Gabor and Jaeger 1995).

Amphibian-Habitat Relationships

As evident in the models to predict amphibian relative abundance for all plots in 2001 and in 2002, one of the most significant habitat features present across the landscape was rock cover. Further, from our cover object use/availability analysis, results suggest significant preferences exist for rock cover, similar to results Herbeck and Larsen (1999) and More et al. (2001) report. Other studies in the literature also support our findings on the positive relationship between rocks and relative abundance and the crucial role of emergent rocks to provide cover, foraging, and nesting sites and to help retain beneficial temperature and moisture regimes (Jaeger 1980, Herrington 1988, Block and Morrison 1998, Pauley and Pauley 1998, Welsh and Lind 1991, Diller and Wallace 1994, Grover 1998, Bosakowski 1999, Herbeck and Larsen 1999, Aubry 2000, Pauley et al. 2000, Welsh and Droege 2001, Ford et al. 2002).

Another important factor in predicting amphibian relative abundance was the distance to water. The influence of aquatic habitats and riparian habitat in SMZs on relative abundance and community distribution, particularly for species who rely on moist environments to complete their life cycles and reproduce successfully, are also well-supported from previous studies (Hairston 1987, Rudolph and Dickson 1990, Buhlman et al. 1993, Foley 1994, Ordiway 1994, Mitchell et al. 1997, Grover and Wilbur 2002, Pauley et al. 2000, Hyde and Simons 2001, Ford et al. 2002). Interestingly, all species captured on non-SMZ plots were also represented on SMZ plots, so protecting habitat in SMZs would protect a broad spectrum of the amphibian community. However, our sampling techniques did not adequately represent species that migrate to and from breeding pools (e.g., *Ambystoma* spp., many frogs, etc.), and these may not be well protected if only narrow SMZs retained a mature forest canopy (Rothermel and Semlitsch 2002, Semlitsch 2002, Semlitsch and Bodie 2003). Cover object use/availability analysis showed that there were significantly more available rocks on SMZ plots, where we captured more amphibians, than on non-SMZ plots, where we captured fewer amphibians.

The third most important variable in predicting abundance was site index. Researchers have documented positive relationships between site moisture, a characteristic described by site index, and relative abundance. Examples of previous studies include Heatwole (1962), Pough et al. (1987), Grover (1998), Harper and Guynn (1999), Grover (2000), and Greenberg (2001).

In all 3 models combining data from both years, there was a significant negative year effect on abundance. This result further supports the idea that estimates of amphibian abundance vary annually probably due to changing weather conditions.

Habitat features that were significant in some models but not others included % woody stems, % canopy cover, soil pH, % herbaceous vegetation, and a count of decomposition classes 3-5 available woody debris.

The importance of overstory canopy cover for maintaining temperature and moisture regimes crucial for amphibian survival has been well-documented, and many studies have reported on positive relationships between intact canopy cover and relative abundance (Heatwole 1962, Pough et al. 1987, Raphael 1988, Wyman 1988, DeGraaf and Rudis 1990, Aubry and Hall 1991, Corn and Bury 1991, Dodd 1991, Welsh and Lind 1996, deMaynadier and Hunter 1998, Bosakowski 1999, Dupuis and Bunnell 1999, Harpole and Haas 1999, Naughton et al. 2000, Barr and Babbitt 2002, Ford et al. 2002, Knapp et al. 2003). The large numbers of missing values for canopy cover (79/151 plots were not measured) in 2001 could be a factor in why this variable did not prove significant in any 2001 model. In addition, we had little variability in this parameter because most of the study site was mature, closed-canopy forest.

Previous studies have examined the negative effects of low soil pH, or higher levels of soil acidity, on salamanders. Physiological reactions of salamanders to acidic environments include toxicity, inhibited uptake of nutrients, and impaired sodium/water balances (Heatwole 1962, Freda and Dunson 1984, Wyman and Hawksley-Lescault 1987, Pais et al. 1988, Wyman 1988, Frisbie and Wyman 1992). Similar to our results, other researchers have discovered positive relationships between increasing soil pH and amphibian abundance (DeGraaf and Rudis 1990, Wyman and Jancola 1992, Ordiway 1994, Frisbie and Wyman 1995, Sugalski and Claussen 1997).

Our models and results of the cover object use/availability analysis demonstrate the importance of highly decomposed (classes 3-5) coarse woody debris (Maser et al. 1979). Highly decomposed wood retains moisture and provides more high-quality cover, nesting, and foraging sites than newly fallen logs and debris and has been shown in previous studies to have positive relationships with increasing salamander abundance (Harmon et al. 1986, Herbeck and Larsen 1999, Aubry et al. 1988, Bury and Corn 1988, Raphael 1988, Wyman 1988, Corn and Bury 1991, Welsh and Lind 1991, Petranka et al. 1994, Dupuis et al. 1995, Brooks 1999, Greenburg 2001).

The amount of herbaceous vegetation present in the habitat had a positive relationship with abundance in one of our models. Other examples of studies that drew similar conclusions about the importance of herbaceous ground and midstory vegetation to provide cover and foraging opportunities for salamanders exist in the literature (Jaeger 1978, Pough et al. 1987, DeGraaf and Rudis 1990, Welsh and Lind 1991, Bosakowski 1999, Brooks 1999, DeGraaf and Yamasaki 2002).

Other habitat variables shown in the literature to have a positive relationship with salamander abundance but that were not significant in any of our 9 models were soil organic layer and leaf litter depths. DeGraaf and Yamasaki (2002) found that depth of organic soil positively effected salamander abundance, and the benefits of a well-developed leaf litter layer for salamanders have also been proven. Leaf litter can provide refugia, foraging and nesting sites, and help salamanders maintain temperature and moisture balances (Heatwole 1962, Jaeger 1978, Pough et al. 1987, Raphael 1988, DeGraaf and Rudis 1990, Corn and Bury 1991, Welsh and Lind 1991, deMaynadier and Hunter 1998). Rather than leaf litter depth or mean biomass, Harpole (1999) found that the variance of leaf litter biomass within plots was a better predictor of relative abundance. This study discovered lower abundance in areas with higher variances, possibly indicating high levels of disturbance, such as higher basal area removal in harvested stands which could wash out leaf litter, piling it up in places, and exposing bare ground in other places (Harpole 1999). Similar to our results, Harper and Guynn (1999) discovered no significant relationship between leaf litter depth and abundance.

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Out of all 9 models over both years, % woody stems was the only habitat characteristic that had a negative relationship with relative abundance. An increase in % woody stems (small saplings and understory woody vegetation $\leq$7.5 cm DBH) usually occurred on recently harvested stands in early successional stages of development. With this scenario, it is expected that relative abundance would be lower because of the well-documented negative effects of timber harvest, particularly clearcutting, on salamander populations (Pough et al. 1987, Ash 1988, Corn and Bury 1991, Petranka et al. 1993, Petranka et al. 1994, Dupuis et al. 1995, Mitchell et al. 1996, Ash 1997, Messere and Ducey 1998, Sattler and Reichenbach 1998, Harper and Guynn 1999, Harpole and Haas 1999, Herbeck and Larsen 1999, Grialou et al. 2000, Knapp et al. 2003).

Our results for woody stems contradict the positive relationship with abundance other studies found for this variable (Heatwole 1962, Raphael 1988, Corn and Bury 1991, Pais et al. 1991, Brooks 1999). However, DeGraaf and Yamasaki (2002) support our findings, while Harper and Guynn (1999) reported no significant relationship between woody stems and abundance.

Cover object use/availability analyses for both years showed that salamanders either preferred rocks over woody debris or showed no preference at all, relative to the amount of available rocks and wood on diagonal transects across 10 m x 10 m plots. Rock size and type preferences for salamanders are not well-documented in the literature. High cobble density, such as was present on our sites, was associated with increased salamander relative abundance in previous studies (although the work has been primarily in the western United States), but use/availability preferences of rock type were not reported (Jaeger 1980, Herrington 1988, Diller and Wallace 1994, Welsh and Lind 1995). My result that flagstones (flat rocks 15-38 cm long) were strongly preferred will allow better identification of high quality salamander habitat for future researchers and forest managers.

Salamanders used wood that was more highly decomposed (class 3-5) and among the smaller width and length classes analyzed. Smaller pieces of woody debris were easier to flip and search thoroughly than larger pieces, so some bias could exist in our method, which consequently, could have affected our results. The longer and larger the log, (e.g., >75 cm wide, >5 m long) the more difficult it would have been for a single person to detect all salamanders in or under that object. Each crewmember differed in his/her ability to move large logs, so there was no standardized procedure for when 2 or more people were needed to move a log or when 1 person could do it alone. Fewer than 10% of logs and woody debris sampled were >20 cm wide, and there was no trend to suggest that salamander use of logs increased as wood size increased, but a bigger sample size in the future with more representation of the intermediate length and width classes could validate our results and eliminate consideration of sampling bias.

Previous studies in the literature suggest that larger, longer logs and woody debris are the most preferred types of wood cover objects. Large, highly decomposed woody debris provides increased availability of cover, foraging, and nesting sites and a greater stability of temperature and moisture (Cline et al. 1980, Maser and Trappe 1984, Harmon et al. 1986, Greenburg 2001).

Considerations for Future Research

Researchers in the future could replicate our methods and resample 10 m x 10 m plots across the MeadWestvaco industrial forest landscape either to support or refute our findings with more sampling data. To expand on previous studies in the literature, researchers could set up controlled experiments to test the importance of variables in our models or in future models instead of replicating descriptive, correlative studies multiple times. Manipulative experiments could also be performed to test preferences I have reported for rock and wood cover object size, shape, and type based on the use/availability analysis.

To refine sampling methods, pilot studies or experiments with crew size could be attempted to examine whether having more people (i.e., 3-5) searching plots increases the probability of amphibian detection on this study site or if 2 people can achieve the same results as a larger crew. Saving personnel and financial resources will continue to be goals on large-scale research projects such as this, so proving that fewer people can produce the same high-quality results as a larger crew would be a worthwhile endeavor.

More work also needs to be done to evaluate our method of sexing light-bellied salamanders in the field with small battery-powered flashlights (often under dark conditions from thick canopy cover and/or inclement weather). By using our techniques in the field, then bringing the same animals back to the lab to re-count using a fiber optic light, and finally performing dissections, we could compare the accuracy of techniques. With more morphological and demographic data on these same salamander populations in the future, results could shed more light on the validity or fallacy of the skewed sex ratios and low fertility and fecundity rates we observed in 2001-2002. Bigger sample sizes could also support the revised size of maturity for the species we measured that had smaller SVL sizes than what Petranka (1998) reported for our region. With larger sample sizes and more replicates, researchers could also investigate differences in size, mass, and overall body condition of species such as redback salamanders or Allegheny Mt. dusky salamanders on SMZ plots vs. non-SMZ plots. The hypothesis here could be that SMZ plots should offer more high quality habitat than upland or non-SMZ plots, therefore allowing salamanders to grow to larger sizes.

Finally, more comprehensive studies could be done on the type and number of available aquatic habitats across the landscape. Since a large percentage (16%) of aquatic habitats we encountered were associated with skidder trails, water bars, and tire ruts, relationships between these artificial habitats and amphibian community composition, fecundity, and relative abundance could be investigated, similar to a previous study by Cromer et al. (2002). In this study researchers discovered that due to the creation of aquatic habitats on skidder trails after timber harvest, relative abundance for some tree frog species (*Hyla* spp.) as well as spotted salamanders (*Ambystoma maculatum*) did not decline or was not significantly different because of canopy removal. Relative abundance of other species such as the marbled salamander (*Ambystoma opacum*) and slimy salamander (*Plethodon glutinosus*) decreased in disturbed areas, despite the availability of new aquatic habitats, because breeding sites under moist logs and leaf litter decreased (Cromer et al. 2002).

CHAPTER 2

TABLES

Table 2.1. Summary of habitat characteristics measured on 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots and used in multiple linear regression analyses (SAS 2002), MeadWestvaco industrial forest, Randolph County, WV. (See "Methods" section for description of variables.)

HABITAT CHARACTERISTIC	2001	2002
basal area (m^2/ha)	x	
% canopy cover (2001: ocular estimate, 2002: spherical densiometer)	x*	x
overstory stem (>7.5 cm DBH) density		x
% woody stems (≤7.5 cm DBH)	x	x
% rock cover	x**	x**
% bare soil	x	x
% herbaceous vegetation	x*	x
% woody debris	x	x
count of decomposition class 1 woody debris along diagonal transects	x	x
count of decomposition class 2 woody debris along diagnonal transects	x	x
count of decomposition class 3 woody debris along diagonal transects	x	x
count of decomposition class 4 woody debris along diagonal transects	x	x
count of decomposition class 5 woody debris along diagonal transects	x	x
count of available rocks along diagonal transects	x	x

SMZ classification (15 m or less from stream or pond	x	x
leaf litter depth (cm)	x	x
C.V. leaf litter depth (cm)		x
leaf litter biomass (g)		x
C. V. leaf litter biomass (g)		x
leaf litter % moisture		x
organic soil layer depth (cm)	x	
C.V. organic soil layer depth (cm)	x	
soil pH		x
stand age (yrs)	x	x
stand type	x	x
site index (*Quercus rubra* base age 50)	x	x

*These variables were not included in some 2001 regression analyses because of large numbers of missing values. (See "Statistical Analyses" section in text for explanation.)

**Percent rock cover was not included in 2001 or 2002 regression analyses; a count of available rocks along diagonal transects was used instead.

Table 2.2. Summary of amphibian species richness and relative abundance on all 2001 10 m x 10 m terrestrial plots (n=151) and all 2002 10 m x 10 m terrestrial plots (n=219), MeadWestvaco industrial forest, Randolph County, WV; total observations include captured and escaped individuals within all plots including unidentifiable *Desmognathus* spp. salamanders.

SPECIES	SCIENTIFIC NAME	TOTAL OBS 2001	TOTAL OBS 2002
Green salamander	*Aneides aeneus*	1	0
American toad	*Bufo americanus*	1	2
N. dusky salamander	*Desmognathus f. fuscus*	161	54
Appalachian seal salamander	*Desmognathus m. monticola*	116	66
Allegheny Mt. dusky salamander	*Desmognathus ochropheus*	210	192
(unidentified dusky salamander)	*Desmognathus* spp.	35	86
N. two-lined salamander	*Eurycea b. bislineata*	42	10
N. spring salamander	*Gyrinophilus p. porphyriticus*	4	2
Four-toed salamander	*Hemidactylum scutatum*	0	1
E. red-spotted newt (eft)	*Notopthalmus v. viridescens*	8	8
Redback salamander	*Plethodon cinereus*	191	91
Slimy salamander	*Plethodon g. glutinosus*	40	33
Wehrle’s salamander	*Plethodon wehrlei*	11	2
Spring peeper	*Pseudacris crucifer*	1	1
Pickerel frog	*Rana palustris*	0	1
Wood frog	*Rana sylvatica*	0	3
TOTAL OBSERVATIONS		**821**	**552**

Table 2.3. Results from Student's t-test analysis of differences in amphibian relative abundance on all 2001 (n=151) and all 2002 10 m x 10 m terrestrial plots (n=219), on 2001 SMZ (n=58) and non-SMZ plots (n=93), and on 2002 SMZ (n=66) and non-SMZ plots (n=153), MeadWestvaco industrial forest, Randolph County, WV; SMZ vs. non-SMZ analyses were done on a per plot basis to correct for the differences in number of plots sampled in each habitat type each year.

2001 TOTAL CAPS	2002 TOTAL CAPS	2001 SMZ CAPS PER PLOT	2001 NON-SMZ CAPS PER PLOT	2002 SMZ CAPS PER PLOT	2002 NON-SMZ CAPS PER PLOT	t	*df*	p
821	552					7.42	368	<0.0001
		8.41 (±0.79)	3.58 (±0.34)			-6.61	149	<0.0001
				5.11 (±0.72)	1.39 (±0.18)	-7.83	217	<0.0001

Table 2.4. Summary of mean captures per plot (± S.E.) by species on 2001 10 m x 10 m SMZ plots (n=58) and non-SMZ plots (n=93) and on 2002 10 m x 10 m SMZ plots (n=66) and non-SMZ plots (n=153), MeadWestvaco industrial forest, Randolph County, WV.

SPECIES	2001 SMZ	2001 NON-SMZ	2002 SMZ	2002 NON-SMZ
Aneides aeneus	0.02 (±0.02)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Bufo americanus	0.02 (±0.02)	0.00 (±0.00)	0.00 (±0.00)	0.01 (±0.01)
Desmognathus f. fuscus	1.97 (±0.28)	0.49 (±0.12)	0.56 (±0.12)	0.10 (±0.03)
Desmognathus m. monticola	1.52 (±0.26)	0.34 (±0.08)	0.97 (±0.25)	0.01 (±0.01)
Desmognathus ochropheus	2.59 (±0.43)	0.65 (±0.14)	1.95 (±0.31)	0.37 (±0.07)
Desmognathus spp.	0.55 (±0.33)	0.32 (±0.02)	0.98 (±0.16)	0.20 (±0.05)
Eurycea b. bislineata	0.66 (±0.16)	0.04 (±0.03)	0.14 (±0.09)	0.01 (±0.01)
Gyrinophilus p. porphyriticus	0.07 (±0.04)	0.00 (±0.00)	0.03 (±0.02)	0.00 (±0.00)
Hemidactylum scutatum	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.01 (±0.01)
Notopthalmus v. viridescens	0.03 (±0.02)	0.07 (±0.03)	0.02 (±0.02)	0.05 (±0.02)
Plethodon cinereus	0.83 (±0.15)	1.54 (±0.18)	0.32 (±0.10)	0.47 (±0.09)
Plethodon g. glutinosus	0.21 (±0.09)	0.31 (±0.06)	0.12 (±0.04)	0.18 (±0.04)
Plethodon wehrlei	0.03 (±0.02)	0.10 (±0.04)	0.00 (±0.00)	0.01 (±0.01)
Pseudacris crucifer	0.00 (±0.00)	0.01 (±0.01)	0.02 (±0.02)	0.00 (±0.00)
Rana palustris	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.01 (±0.01)
Rana sylvatica	0.00 (±0.00)	0.00 (±0.00)	0.03 (±0.03)	0.01 (±0.01)
ALL SPECIES COMBINED	**8.41** (±0.79)	**3.58** (±0.34)	**5.11** (±0.72)	**1.39** (±0.18)

Table 2.5. Results from Student's t-test analysis differences in relative abundance for the 6 most common captured and processed salamander species on 2001 10 m x 10 m SMZ (n=58) vs. non-SMZ plots (n=93) and on 2002 10 m x 10 m SMZ (n=66) vs. non-SMZ plots (n=153), MeadWestvaco industrial forest, Randolph County, WV; analyses were done on a per plot basis to correct for the differences in number of plots sampled in each habitat type each year.

SPECIES	2001 SMZ CAPS PER PLOT	2001 NON-SMZ CAPS PER PLOT	2002 SMZ CAPS PER PLOT	2002 NON-SMZ CAPS PER PLOT	t	*df*	p
Desmognathus f. fuscus	1.97 (±0.28)	0.49 (±0.12)			-6.80	149	<0.0001
			0.56 (±0.12)	0.10 (±0.03)	-6.09	217	<0.0001
Desmognathus ochropheus	2.59 (±0.43)	0.65 (±0.14)			-5.90	149	<0.0001
			1.95 (±0.31)	0.37 (±0.07)	-8.64	217	<0.0001
Desmognathus m. monticola	1.52 (±0.26)	0.34 (±0.08)			-5.97	149	<0.0001
			0.97 (±0.25)	0.01 (±0.01)	-5.92	217	<0.0001
Eurycea b. bislineata	0.66 (±0.16)	0.04 (±0.03)			-4.73	149	<0.0001
			0.14 (±0.09)	0.01 (±0.01)	-2.16	217	0.0320
Plethodon cinereus	0.83 (±0.02)	1.54 (±0.18)			0.80	149	0.4225
			0.32 (±0.10)	0.47 (±0.09)	-1.29	217	0.1999
Plethodon g. glutinosus	0.21 (±0.09)	0.31 (±0.06)			-0.08	149	0.9365
			0.12 (±0.04)	0.18 (±0.04)	-1.12	217	0.2636

Table 2.6. Results from Simpson's index of amphibian diversity (Krebs 1999) for 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots, 2001 (n=58) and 2002 (n=66) SMZ plots only, and 2001 (n=93) and 2002 (n=153) non-SMZ plots only, MeadWestvaco industrial forest, Randolph County, WV; values reflect the probability of capturing 2 individuals at random that are from different species. (Escaped/unidentified *Desmognathus* spp. were not included in analysis.)

PLOTS	2001	2002
All	0.798	0.743
SMZ	0.792	0.684
Non-SMZ	0.729	0.724

Table 2.7. Summary of mean morphological characteristics (± S.E.) by species and sex from all 2001 10 m x 10 m terrestrial plots (n=151) for all captured and processed salamanders, MeadWestvaco industrial forest, Randolph County, WV.

SPECIES	SEX	N	SVL (mm)	TL (mm)	MASS (g)	M/SVL RATIO (g/mm)
Desmognathus f. fuscus	M	43	36 (±0.69)	67 (±1.46)	0.89 (±0.05)	0.024 (±0.001)
	F	51	34 (±0.47)	65 (±1.08)	0.78 (±0.04)	0.022 (±0.001)
	J	65	24 (±0.50)	45 (±1.08)	0.28 (±0.01)	0.011 (±0.000)
Desmognathus m. monticola	M	53	40 (±0.52)	74 (±1.42)	1.15 (±0.05)	0.028 (±0.001)
	F	30	40 (±1.24)	78 (±2.56)	1.42 (±0.23)	0.033 (±0.003)
	J	21	28 (±1.05)	53 (±2.41)	0.44 (±0.04)	0.015 (±0.001)
Desmognathus ochropheus	M	61	37 (±0.52)	68 (±1.22)	0.91 (±0.38)	0.024 (±0.001)
	F	55	35 (±0.47)	64 (±1.20)	0.77 (±0.03)	0.022 (±0.001)
	J	94	23 (±0.38)	43 (±0.93)	0.28 (±0.01)	0.011 (±0.000)
Eurycea b. bislineata	A	23	38 (±0.93)	77 (±2.12)	0.69 (±0.04)	0.018 (±0.001)
	J	17	24 (±0.89)	47 (±2.53)	0.22 (±0.03)	0.009 (±0.001)
Gyrinophilus p. porphyriticus	M	1	72 (±0.00)	120 (±0.00)	6.32 (±0.00)	0.087 (±0.000)
	F	1	63 (±0.00)	106 (±0.00)	4.80 (±0.00)	0.076 (±0.000)
Plethodon cinereus	M	44	36 (±0.47)	65 (±1.07)	0.76 (±0.03)	0.021 (±0.001)
	F	38	37 (±0.37)	67 (±1.01)	0.74 (±0.02)	0.020 (±0.001)
	J	98	27 (±0.51)	47 (±1.25)	0.37 (±0.02)	0.013 (±0.001)
Plethodon g. glutinosus	A	13	67 (±1.98)	119 (±4.78)	6.16 (±0.46)	0.091 (±0.005)
	J	23	32 (±1.36)	56 (±2.81)	0.66 (±0.06)	0.019 (±0.001)
Plethodon wehrlei	J	10	41 (±3.87)	73 (±7.96)	1.28 (±0.32)	0.027 (±0.005)

Table 2.8. Summary of mean morphological characteristics (± S.E.) by species and sex from all 2002 10 m x 10 m terrestrial plots (n=219), for all captured and processed salamanders, MeadWestvaco industrial forest, Randolph County, WV.

SPECIES	SEX	N	SVL (mm)	TL (mm)	MASS (g)	M/SVL RATIO (g/mm)
Desmognathus f. fuscus	M	21	41 (±1.97)	70 (±3.79)	1.40 (±0.30)	0.032 (±0.004)
	F	20	39 (±2.09)	67 (±1.99)	0.77 (±0.07)	0.021 (±0.002)
	J	9	26 (±1.20)	48 (±3.42)	0.36 (±0.02)	0.013 (±0.001)
Desmognathus m. monticola	M	7	50 (±4.71)	91 (±8.10)	2.97 (±0.94)	0.053 (±0.012)
	F	24	50 (±2.37)	90 (±4.41)	2.81 (±0.44)	0.052 (±0.006)
	J	19	21 (±1.54)	38 (±3.19)	0.26 (±0.06)	0.010 (±0.002)
Desmognathus ochropheus	M	78	38 (±0.47)	71 (±1.16)	0.99 (±0.04)	0.026 (±0.001)
	F	46	38 (±0.80)	72 (±2.01)	1.02 (±0.14)	0.026 (±0.002)
	J	56	23 (±0.83)	44 (±1.97)	0.32 (±0.03)	0.012 (±0.001)
Eurycea b. bislineata	A	1	38 (±0.00)	85 (±0.00)	0.60 (±0.00)	0.020 (±0.000)
	J	8	22 (±1.78)	41 (±4.73)	0.25 (±0.06)	0.010 (±0.001)
Gyrinophilus p. porphyriticus	J	1	39 (±0.00)	67 (±0.00)	1.25 (±0.00)	0.032 (±0.000)
Hemidactylum scutatum	F	1	35 (±0.00)	76 (±0.00)	0.88 (±0.00)	0.026 (±0.000)
Notopthalmus v. viridescens	J	5	34 (±3.98)	63 (±6.35)	1.23 (±0.54)	0.032 (±0.011)
Plethodon cinereus	M	16	37 (±0.68)	66 (±1.83)	0.78 (±0.04)	0.021 (±0.001)
	F	36	37 (±0.39)	67 (±1.12)	0.68 (±0.02)	0.019 (±0.001)
	J	33	27 (±0.89)	48 (±2.16)	0.36 (±0.03)	0.012 (±0.001)

SPECIES	SEX	N	SVL (mm)	TL (mm)	MASS (g)	M/SVL RATIO (g/mm)
Plethodon g. glutinosus	M	2	65	121	6.25	0.097
			(±2.50)	(±6.00)	(±0.67)	(±0.007)
	F	5	61	116	5.56	0.088
			(±3.25)	(±6.82)	(±0.90)	(±0.009)
	J	18	29	53	0.66	0.020
			(±1.99)	(±3.89)	(±0.11)	(±0.003)
Plethodon wehrlei	J	2	30	53	0.44	0.015
			(±1.50)	(±2.00)	(±0.05)	(±0.001)

Table 2.9. Summary of sex ratio and age class distribution by species for the 6 most common captured and processed salamander species from 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

SPECIES	2001 MALE : FEMALE	2002 MALE : FEMALE	2001 JUVENILE : ADULT	2002 JUVENILE : ADULT
Desmognathus f. fuscus	1 : 1.21 (n=43) (n=51)	1 : 0.95 (n=21) (n=20)	1 : 1.45 (n=65) (n=94)	1 : 4.67 (n=9) (n=42)*
Desmognathus m. monticola	1 : 0.57 (n=53) (n=30)	1 : 3.43 (n=7) (n=24)	1 : 4.00 (n=21) (n=84)*	1 : 1.63 (n=19) (n=31)
Desmognathus ochropheus	1 : 0.96 (n=61) (n=55)	1 : 0.59 (n=78) (n=46)	1 : 1.23 (n=94) (n=116)	1 : 2.35 (n=55) (n=129)*
Eurycea b. bislineata	**	**	1 : 1.35 (n=17) (n=23)*	1 : 0.13 (n=8) (n=1)*
Plethodon cinereus	1 : 0.86 (n=44) (n=38)	1 : 2.25 (n=16) (n=36)	1 : 0.85 (n=98) (n=83)*	1 : 1.58 (n=33) (n=52)
Plethodon g. glutinosus	**	1 : 2.50 (n=2) (n=5)	1 : 0.56 (n=23) (n=13)*	1 : 0.39 (n=18) (n=7)

* sample size includes adult salamanders whose sex was not determined

** adult sex data not collected

Table 2.10. Summary of gravid females and mean clutch sizes (± S.E.) per species on all 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV. Percent gravid females reflects percentage of all captured and processed females in a species discovered with yolked eggs, and mean # eggs per female only includes eggs each female was carrying at the time of capture, not eggs found in nests. (No gravid female redback salamanders were found in 2002.)

SPECIES	% GRAVID (2001)	% GRAVID (2002)	MEAN # EGGS/FEM (2001)	MEAN # EGGS/FEM (2002)
Desmognathus f. fuscus	16 (8/51)	5 (1/20)	11.6 (±1.1)	12.0 (±0.0)
Desmognathus m. monticola	13 (4/30)	21 (5/24)	11.8 (±2.3)	19.0 (±5.1)
Desmognathus ochropheus	13 (7/55)	20 (9/46)	10.6 (±1.0)	13.9 (±1.9)
Plethodon cinereus	5 (2/38)	0 (0/36)	4.0 (±3.0)	N/A

Table 2.11. Proportion of captured, processed salamanders with missing or regenerating tails on 2001 10 m x 10 m SMZ plots (n=58) vs. non-SMZ plots (n=93) and on 2002 10 m x 10 m SMZ plots (n=66) vs. non-SMZ plots (n=153), MeadWestvaco industrial forest, Randolph County, WV.

YEAR	SMZ	NON-SMZ	X^2	*df*	p
2001	10% (42/429)	12% (38/312)	1.062	739	0.3028
2002	2% (5/248)	4% (7/168)	1.614	414	0.2040

Table 2.12. Summary of % frequencies of forest stand types encountered on 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots and approximate percentage of each type available across the landscape, according to MeadWestvaco's GIS database, MeadWestvaco industrial forest, Randolph County, WV. (See "Methods" section for definitions of stand types.)

STAND TYPE	% FREQUENCY	N	% AVAILABLE
	<u>2001</u>		
Cove Hardwood	12.6	19	5
Mountain Hardwood	78.8	119	88
Open/Nonforest	1.3	2	2
Upland Hardwood	7.3	11	5
	<u>2002</u>		
Cove Hardwood	7.4	16	5
Mountain Hardwood	82.7	181	88
Open/Nonforest	1.4	3	2
Upland Hardwood	7.4	16	5

Table 2.13. Summary of % frequencies of cover classes (Daubenmire 1959) for ground and mid-story habitat characteristics on 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

HABITAT CHARACTERISTIC	% FREQ CLS 0 (<5%)	% FREQ CLS 1 (5-25%)	% FREQ CLS 2 (26-50%)	% FREQ CLS 3 (51-75%)	% FREQ CLS 4 (76-95%)	% FREQ CLS 5 (>95%)	TOTAL N
			2001				
% bare soil	65.9 (n=84)	29.5 (n=38)	3.1 (n=4)	1.6 (n=2)	0.0 (n=0)	0.0 (n=0)	128
% rock	41.9 (n=62)	36.5 (n=54)	16.9 (n=25)	4.1 (n=6)	0.7 (n=1)	0.0 (n=0)	148
% woody debris	19.9 (n=29)	48.0 (n-70)	26.7 (n=39)	4.8 (n=7)	0.7 (n=1)	0.0 (n=0)	146
% woody stems (≤7.5 DBH cm)	42.2 (n=54)	39.8 (n=51)	12.5 (n=16)	3.9 (n=5)	1.6 (n=2)	0.0 (n=0)	128
% herbaceous vegetation	14.5 (n=10)	40.6 (n=28)	21.7 (n=15)	18.8 (n=13)	4.4 (n=3)	0.0 (n=0)	69
			2002				
% bare soil	57.8 (n=126)	30.1 (n=66)	10.6 (n=23)	0.5 (n=1)	1.4 (n=3)	0.0 (n=0)	219
% rock	52.5 (n=115)	35.8 (n=78)	10.1 (n=22)	1.8 (n=4)	0.0 (n=0)	0.0 (n=0)	219
% woody debris	24.8 (n=54)	56.6 (n-124)	15.1 (n=33)	3.2 (n=7)	0.5 (n=1)	0.0 (n=0)	219
% woody stem (≤7.5 DBH cm)	43.4 (n=95)	45.0 (n=98)	10.6 (n=23)	0.9 (n=2)	0.4 (n=1)	0.0 (n=0)	219
% herbaceous vegetation	34.9 (n=76)	38.1 (n=83)	20.1 (n=44)	4.1 (n=9)	3.2 (n=7)	0.0 (n=0)	219

Table 2.14. Summary statistics for continuous habitat data from 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

HABITAT CHARACTERISTIC	N	MEAN	S.E.	VAR	MIN	MAX
		2001				
Stand age (yrs)	151	72.0	1.365	281.54	2	89
Site index	150	72.0	0.340	17.31	60	85
Basal area (m^2/ha)	115	26.0	1.471	248.73	0	72
Mean leaf litter depth (cm)	151	5.7	0.186	5.21	0	14
Mean organic soil layer depth (cm)	151	13.5	0.384	22.22	0	25
% canopy cover	72	75.0	1.872	252.42	25	95
Count of available woody debris (decomposition classes 1-2) along diagonal transects	132	0.8	0.112	1.66	0	8
Count of available woody debris (decomposition classes 3-5) along diagonal transects	132	5.8	0.327	14.12	0	19
Count of available rocks along diagonal transects	132	3.5	0.411	22.25	0	24
		2002				
Stand age (yrs)	216	70.0	1.577	532.11	1	92
Site index	216	70.0	0.560	67.70	60	80
Overstory stem density (# trees >7.5 cm DBH/plot)	219	2.3	1.628	0.09	0	6
Mean leaf litter depth (cm)	218	2.6	0.107	2.49	0	8.1
Mean leaf litter biomass (g/0.25m^2)	219	25.6	0.880	169.78	0	95.4
Mean leaf litter % moisture	219	49.9	1.423	442.44	0	88.0
Soil pH	210	4.1	0.050	0.56	3.0	8.2
% canopy cover	219	84.0	1.516	503.12	0	98
Count of available woody debris (decomposition classes 1-2) along diagonal transects	219	1.4	0.116	2.97	0	8
Count of available woody debris (decomposition classes 3-5) along diagonal transects	219	3.3	0.165	5.80	0	14
Count of available rocks along diagonal transects	219	3.7	0.271	16.06	0	25

Table 2.15. Results from stepwise multiple linear regression analyses (SAS 2002) at the 0.10 level to predict amphibian relative abundance on 2001 and 2002 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

VARIABLE	SYMBOL	*B*	S.E.	p	F	*df*	p
General model for all plots	Y_G				50.18	304	<0.0001
SMZ class	SMZ	0.87	0.105	<0.0001			
Year	yr	-0.75	0.099	<0.0001			
Available rocks	avrk	0.03	0.011	0.0018			
Site index	s.i.	0.02	0.011	0.0696			
General SMZ model	Y_{GSMZ}				13.52	106	0.0004
Year	yr	-0.76	0.201	0.0004			
Available rocks	avrk	0.04	0.021	0.0448			
General Non-SMZ model	Y_{GNON}				15.12	190	<0.0001
Year	yr	-0.75	0.115	<0.0001			
Available rocks	avrk	0.03	0.010	0.0300			
% woody stems (≤7.5 cm DBH)	wstm	-0.12	0.061	0.0496			
Site index	s.i.	0.02	0.012	0.0744			
2001 model	Y_A				13.97	88	<0.0001
SMZ class	SMZ	0.97	0.175	<0.0001			
Site index	s.i.	0.07	0.023	0.0065			
Available rocks	avrk	0.03	0.016	0.0945			
2001 SMZ model	Y_{ASMZ}				7.18	40	0.0022
Site index	s.i.	0.15	0.048	0.0083			
% herbaceous vegetation	veg	0.33	0.139	0.0210			
2001 Non-SMZ model	Y_{ANON}				7.35	41	0.0019
Available rocks	avrk	0.06	0.020	0.0048			
Site index	s.i.	0.06	0.025	0.0310			
2002 model	Y_B				17.50	198	<0.0001
SMZ class	SMZ	0.75	0.115	<0.0001			
Soil pH	pH	0.23	0.068	0.0048			
% canopy	cnpy	0.01	0.002	0.0619			
Available rocks	avrk	0.04	0.013	0.0081			
% woody stems (≤7.5 cm DBH)	wstm	-0.17	0.070	0.0175			
Available woody debris (decomp. classes 3-5)	avwd	0.05	0.022	0.0232			

VARIABLE	SYMBOL	*B*	S.E.	p	F	*df*	p
2002 SMZ model	Y_{BSMZ}				8.82	59	<0.0001
Soil pH	pH	0.34	0.131	0.0031			
Available rocks	avrk	0.09	0.029	0.0151			
% canopy	cnpy	0.08	0.028	0.0064			
2002 Non-SMZ model	Y_{BNON}				6.74	138	0.0003
% canopy	cnpy	0.01	0.002	0.0026			
% woody stems (≤7.5 cm DBH)	wstm	-0.17	0.065	0.0106			
Available woody debris (decomp. classes 3-5)	avwd	0.04	0.021	0.0663			

Table 2.16. Summaries of 9 significant models at the 0.10 level from results of stepwise multiple linear regression analyses (SAS 2002) to predict amphibian relative abundance on 2001 and 2002 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV; an asterisk (*) denotes the best model to use in actual predictions based on highest R^2_{PRESS}. (See Table 2.17 for definitions of model variables.)

MODEL TYPE	R^2	ADJ R^2	R^2_{PRESS}	MODEL
General model for all plots,	0.3977	0.3664	0.3510	*Y_G=1.27 + 0.87(SMZ) – 0.75(yr) + 0.03(avrk) - 0.17(wstm) + 0.05(avwd)
General SMZ model	0.1467	0.1300	0.1022	Y_{GSMZ}=3.45 – 0.76(yr) + 0.04(avrk)
General Non-SMZ model	0.2415	0.2462	0.2202	Y_{GNON}=1.43 – 0.75(yr) + 0.03(avrk) – 0.12(wstm) + 0.02(s.i.)
2001 model	0.3226	0.3076	0.2572	Y_A= -3.14 + 0.97(SMZ) + 0.07(s.i.) + 0.03(avrk)
2001 SMZ model	0.2641	0.1635	0.0937	Y_{ASMZ}= -8.49 + 0.15(s.i.) + 0.33(veg)
2001 Non-SMZ model	0.2640	0.1781	0.1217	Y_{ANON}= -2.24 + 0.06(avrk) + 0.06(s.i.)
2002 model	0.3466	0.3336	0.2864	Y_B= -0.56 + 0.75(SMZ) + 0.23(pH) + 0.01(cnpy) + 0.04(avrk) – 0.17(wstm) + 0.05(avwd)
2002 SMZ model	0.3097	0.2760	0.2711	Y_{BSMZ}= -6.96 + 0.09(avrk) + 0.34(pH) + 0.08(cnpy)
2002 Non-SMZ model	0.1279	0.1022	0.0811	Y_{BNON}=0.68 + 0.01(cnpy) – 0.17(wstm) + 0.04(avwd)

Table 2.17. Mean proportions (± S.E.) of used and available rock and woody debris cover objects from 2001 (n=117) and 2002 (n=126) 10 m x 10 m terrestrial plots, 2001 (n=51) and 2002 (n=53) SMZ plots only, and 2001 (n=66) and 2002 (n=73) non-SMZ plots only, MeadWestvaco industrial forest, Randolph County, WV.

PLOTS	COVER OBJECT	PROPORTION USED	PROPORTION AVAILABLE
		2001	
All (n=117)	Rock	0.49 ± 0.03	0.33 ± 0.02
	Wood	0.51 ± 0.03	0.67 ± 0.02
SMZ only (n=51)	Rock	0.42 ± 0.04	0.46 ± 0.03
	Wood	0.58 ± 0.04	0.54 ± 0.03
Non-SMZ only (n=66)	Rock	0.55 ± 0.05	0.23 ± 0.03
	Wood	0.45 ± 0.05	0.77 ± 0.03
		2002	
All (n=126)	Rock	0.60 ± 0.04	0.41 ± 0.03
	Wood	0.40 ± 0.04	0.59 ± 0.03
SMZ only (n=53)	Rock	0.67 ± 0.05	0.49 ± 0.04
	Wood	0.33 ± 0.05	0.51 ± 0.04
Non-SMZ only (n=73)	Rock	0.54 ± 0.05	0.36 ± 0.04
	Wood	0.46 ± 0.05	0.64 ± 0.04

Table 2.18. Results of compositional analysis (SAS 2002) for salamander cover object preferences from 2001 and 2002 terrestrial sampling on both 10 m x 10 m SMZ and non-SMZ plots separate and combined, MeadWestvaco industrial forest, Randolph County, WV. The values shown are from t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

All 2001 Plots

	Rock	Wood	RANK
Rock		3.0098* (0.004)	1
Wood		.	0

All 2002 Plots

	Rock	Wood	RANK
Rock		5.0926* (0.001)	1
Wood		.	0

2001 SMZ Plots

	Rock	Wood	RANK
Rock		-0.5397 (0.590)	0
Wood		.	1

2002 SMZ Plots

	Rock	Wood	RANK
Rock		4.0601* (0.001)	1
Wood		.	0

2001 Non-SMZ Plots

	Rock	Wood	RANK
Rock		3.8186* (0.001)	1
Wood		.	0

2002 Non-SMZ Plots

	Rock	Wood	RANK
Rock		3.5341* (0.001)	1
Wood		.	0

*Indicates a significant preference at the 0.10 level for a type of cover object. (The smallest p-value possible is 0.001.)

Table 2.19. Mean proportions (± S.E.) of used and available rock length (cm) classes on 2001 10 m x 10 m terrestrial plots (n=82), MeadWestvaco industrial forest, Randolph County, WV.

ROCK LENGTH CLASS	PROPORTION USED	PROPORTION AVAILABLE
5-10 cm	0.05 ± 0.014	0.06 ± 0.013
11-20 cm	0.29 ± 0.034	0.32 ± 0.037
21-30 cm	0.35 ± 0.037	0.28 ± 0.034
31-40 cm	0.20 ± 0.031	0.12 ± 0.022
41-50 cm	0.06 ± 0.021	0.11 ± 0.024
51-60 cm	0.03 ± 0.013	0.03 ± 0.015
61-70 cm	0.01 ± 0.004	0.03 ± 0.015
>70 cm	0.01 ± 0.003	0.05 ± 0.015

Table 2.20. Results of compositional analysis (SAS 2002) for salamander preferences of rock length (cm) classes from 200110 m x 10 m plots (n=82), MeadWestvaco industrial forest, Randolph County, WV. The matrices shown are of t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

	5-10	11-20	21-30	31-40	41-50	51-60	61-70	>70	RANK
5-10	.	-0.2808 (0.763)	-1.0605 (0.288)	-1.3674 (0.179)	0.3037 (0.777)	-0.0814 (0.940)	0.1601 (0.888)	1.3019 (0.207)	3
11-20		.	-0.7539 (0.447)	-0.9662 (0.311)	0.5214 (0.631)	0.1814 (0.850)	0.3906 (0.710)	1.4060 (0.151)	5
21-30			.	-0.0943 (0.924)	1.3236 (0.185)	1.1383 (0.254)	1.3568 (0.174)	2.2169* (0.029)	6
31-40				.	1.4978 (0.134)	1.5413 (0.126)	1.6340 (0.115)	2.4888* (0.016)	7
41-50					.	-0.4294 (0.701)	-0.2188 (0.825)	1.0226 (0.325)	1
51-60						.	0.3162 (0.755)	2.0317* (0.040)	4
61-70							.	1.6455 (0.109)	2
>70								.	0

*Indicates a significant preference at the 0.10 level for a rock length (cm) class. (The smallest p-value possible is 0.001.)

Table 2.21. Mean proportions (+ S.E.) of used and available rock shape and rock type classes (USDA 1998) from 2002 10 m x 10 m terrestrial plots (n=92), MeadWestvaco industrial forest, Randolph County, WV).

ROCK CLASS	PROPORTION USED	PROPORTION AVAILABLE
	SHAPE	
Flat	0.68 + 0.042	0.56 + 0.035
All Other Shapes	0.32 + 0.042	0.44 + 0.035
	TYPE	
Channer (flat: 0.2-15 cm long)	0.17 + 0.032	0.22 + 0.030
Cobble (round or angular: 7.5-25 cm diameter)	0.16 + 0.033	0.22 + 0.028
Flagstone (flat: 15-38 cm long)	0.40 + 0.044	0.23 + 0.026
Stone (round or angular: 25-60 cm diameter) (flat: 38-60 cm long)	0.20 + 0.033	0.23 + 0.027
Boulder (round, angular, or flat: >60 cm diameter)	0.07 + 0.021	0.10 + 0.018

Table 2.22. Results of compositional analysis (SAS 2002) for salamander preferences of rock shape (i.e., flat vs. all other shapes) and type (i.e., boulder, channer, cobble, flagstone, and stone) (USDA 1998) from all 2002 10 m x 10 m plots (n=92), MeadWestvaco industrial forest, Randolph County, WV. The matrices shown are of t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

ROCK SHAPE

	Flat	Other	RANK
Flat	.	3.5871* (0.002)	1
Other		.	0

ROCK TYPE

	Boul	Chan	Cob	Flag	Stn	RANK
Boul	.	1.2509 (0.231)	1.6702* (0.094)	-1.5740 (0.125)	0.8825 (0.395)	3
Chan		.	0.2831 (0.790)	-2.4733* (0.022)	-0.4288 (0.666)	1
Cob			.	-2.6740* (0.010)	-0.7235 (0.484)	0
Flag				.	2.1699* (0.039)	4
Stn					.	2

*Indicates a significant preference at the 0.10 level for a rock shape or type. (The smallest p-value possible is 0.001.)

Table 2.23. Mean proportions (± S.E.) of used and available woody debris decomposition classes (Maser et al. 1979) on 2001 (n=94) and 2002 (n=78) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

WOOD DECOMPOSITION CLASSES	PROPORTION USED	PROPORTION AVAILABLE
	2001	
Classes 1-2	0.05 ± 0.020	0.12 ± 0.020
Classes 3-5	0.95 ± 0.020	0.88 ± 0.020
	2002	
Classes 1-2	0.19 ± 0.039	0.26 ± 0.030
Classes 3-5	0.81 ± 0.039	0.74 ± 0.030

Table 2.24. Results of compositional analysis (SAS 2002) for salamander preferences of woody debris decomposition classes (i.e., classes 1-2 vs. classes 3-5) (Maser et al. 1979) from 2001(n=94) and 2002 (n=78) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV. The matrices shown are of t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

2001

	Cl. 1-2	Cl. 3-5	RANK
Cl. 1-2	.	-3.9321* (0.001)	0
Cl. 3-5		.	1

2002

	Cl. 1-2	Cl. 3-5	RANK
Cl. 1-2		-2.1173* (0.001)	0
Cl. 3-5		.	1

*Indicates a significant preference at the 0.10 level for woody debris decomposition classes. (The smallest p-value possible is 0.001.)

Table 2.25. Mean proportions (± S.E.) of used and available woody debris width (cm) classes on 2001 (n=117) and 2002 (n=126) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

WOOD WIDTH CLASSES	PROPORTION USED	PROPORTION AVAILABLE
	2001	
5-10 cm	0.67 ± 0.038	0.63 ± 0.029
11-20 cm	0.28 ± 0.036	0.26 ± 0.026
>20 cm	0.05 ± 0.020	0.11 ± 0.172
	2002	
5-10 cm	0.71 ± 0.050	0.69 ± 0.031
11-20 cm	0.20 ± 0.040	0.20 ± 0.025
>20 cm	0.09 ± 0.030	0.11 ± 0.024

Table 2.26. Results of compositional analysis (SAS 2002) for salamander preferences of woody debris width (cm) classes from 2001 (n=94) and 2002 (n=78) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV. The matrices shown are of t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

2001

	5-10	11-20	>20	RANK
5-10	.	0.9501 (0.332)	1.9848* (0.053)	2
11-20		.	0.7769 (0.444)	1
>20			.	0

2002

	5-10	11-20	>20	RANK
5-10	.	0.9955 (0.310)	0.6387 (0.512)	2
11-20		.	-0.4617 (0.636)	0
>20			.	1

*Indicates a significant preference at the 0.10 level for woody debris width (cm) classes. (The smallest p-value possible is 0.001.)

Table 2.27. Mean proportions (± S.E.) of used and available woody debris length (cm) classes on 2001 (n=94) and 2002 (n=78) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV.

WOOD LENGTH CLASS	PROPORTION USED	PROPORTION AVAILABLE
	2001	
≤50 cm	0.34 ± 0.038	0.14 ± 0.019
51-100 cm	0.39 ± 0.038	0.29 ± 0.024
101-150 cm	0.09 ± 0.022	0.11 + 0.013
151-200 cm	0.07 ± 0.021	0.10 ± 0.015
201-250 cm	0.02 ± 0.006	0.06 ± 0.011
251-300 cm	0.02 ± 0.008	0.05 ± 0.009
>300 cm	0.07 ± 0.024	0.25 ± 0.027
	2002	
≤50 cm	0.21 ± 0.043	0.13 ± 0.021
51-100 cm	0.41 ± 0.051	0.30 ± 0.029
101-150 cm	0.13 ± 0.035	0.10 ± 0.020
151-200 cm	0.08 ± 0.029	0.11 ± 0.016
201-250 cm	0.02 ± 0.013	0.03 ± 0.009
251-300 cm	0.02 ± 0.014	0.08 ± 0.016
>300 cm	0.13 ± 0.036	0.25 ± 0.031

Table 2.28. Results of compositional analysis (SAS 2002) for salamander preferences of woody debris length (cm) classes from 2001 (n=94) and 2002 (n=78) 10 m x 10 m terrestrial plots, MeadWestvaco industrial forest, Randolph County, WV. The matrices shown are of t-statistics with ranks of preference for cover objects calculated from tallying positive and negative significant differences (higher rank=more preferred).

2001

	≤50	51-100	101-150	151-200	201-250	251-300	>300	RANK
≤50	.	1.9758 (0.43)	3.3101* (0.002)	3.9112* (0.001)	4.3434* (0.001)	4.7874* (0.001)	6.7158* (0.001)	6
51-100		.	1.3788 (0.171)	1.5048 (0.153)	2.0778* (0.039)	1.7175* (0.071)	4.4067* (0.001)	5
101-150			.	0.1655 (0.869)	0.4336 (0.696)	0.1967 (0.855)	3.2160* (0.001)	4
151-200				.	0.2709 (0.792)	0.0043 (0.997)	3.0603* (0.004)	3
201-250					.	-0.3539 (0.711)	3.9243* (0.001)	1
251-300						.	3.8431* (0.001)	2
>300							.	0

2002

	≤50	51-100	101-150	151-200	201-250	251-300	>300	RANK
≤50	.	0.6008 (0.540)	0.1892 (0.855)	1.4174 (0.156)	-0.4671 (0.625)	1.5340 (0.124)	2.8876* (0.007)	5
51-100		.	-0.4600 (0.629)	0.5469 (0.603)	-1.1857 (0.261)	0.6553 (0.527)	2.4642* (0.013)	3
101-150			.	1.0473 (0.314)	-0.6723 (0.487)	1.1497 (0.229)	2.9624* (0.001)	4
151-200				.	-1.9662* (0.055)	0.0271 (0.984)	1.7573* (0.086)	2
201-250					.	2.3204* (0.022)	4.4279* (0.001)	6
251-300						.	2.0249* (0.046)	1
>300							.	0

*Indicates a significant preference at the 0.10 level for wood length (cm) classes. (The smallest p-value possible is 0.001.)

CHAPTER 2

FIGURES

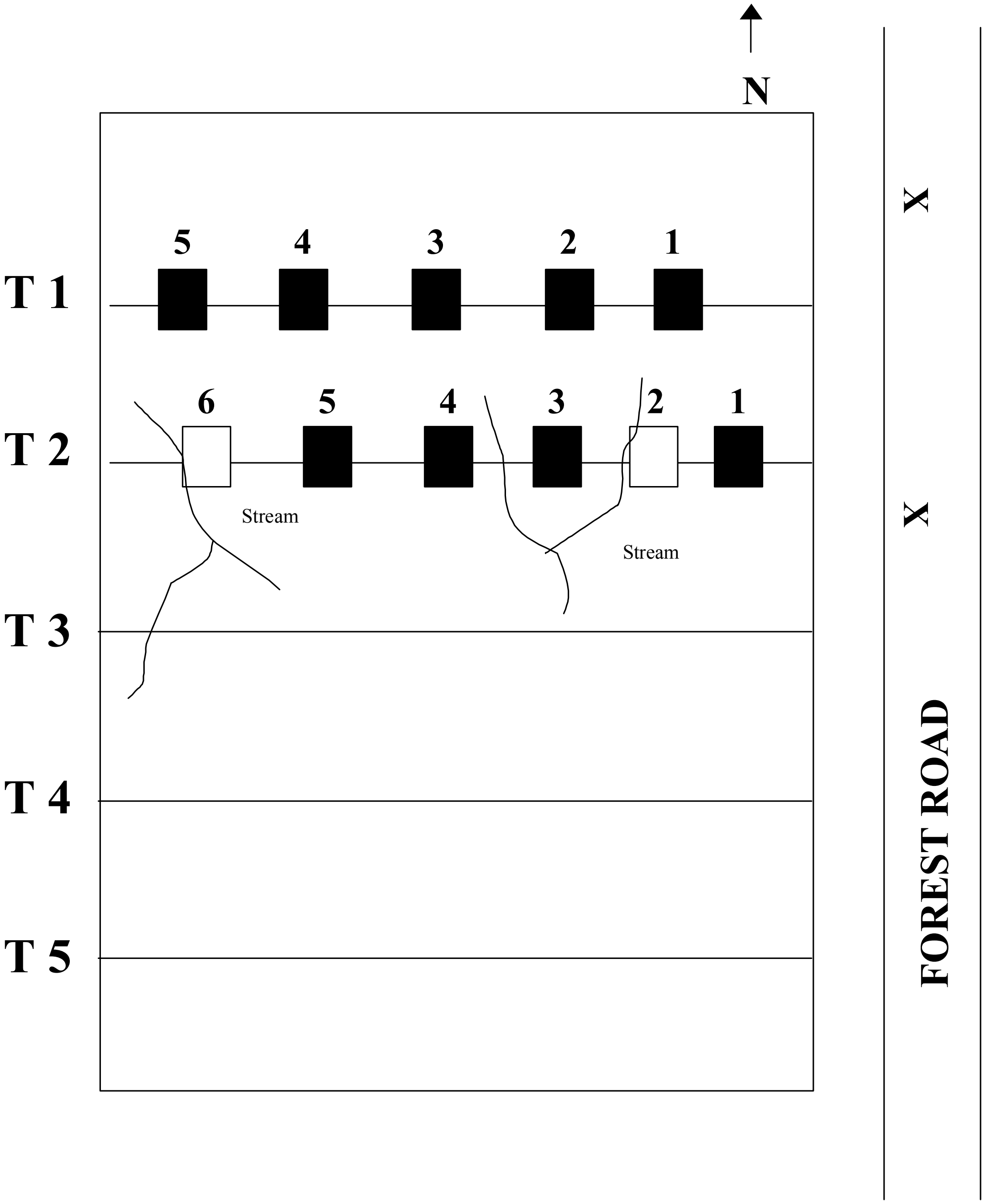

Figure 2.1. Theoretical diagram (not to scale) of a forest compartment with east-west transects and random-systematic 10 m x 10 m terrestrial sampling plots accessed randomly near forest road markers (Xs); transect 2 shows SMZ plots (clear squares) at every other perennial or ephemeral stream, MeadWestvaco industrial forest, Randolph County, WV.

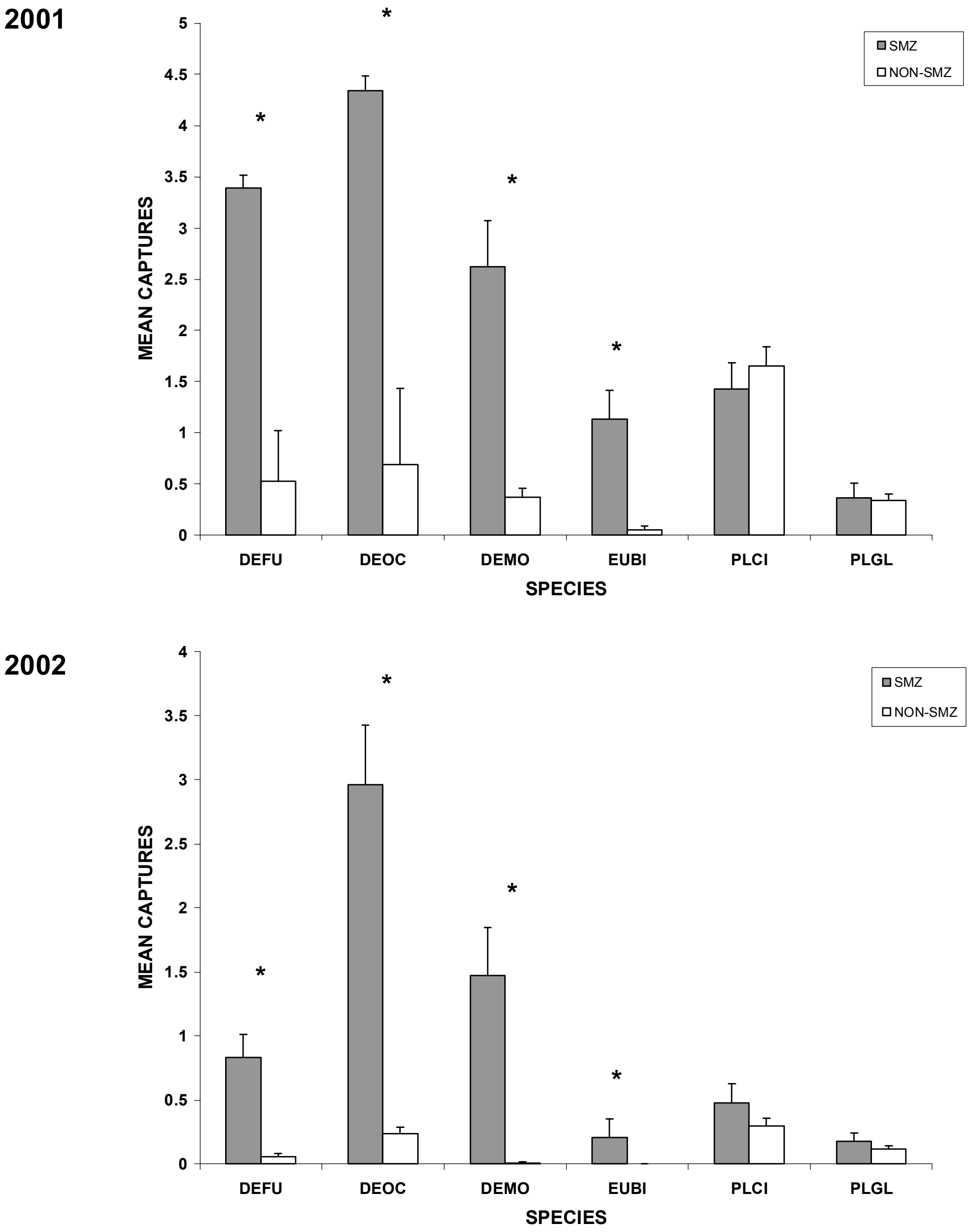

Figure 2.2. Histograms showing differences in relative abundance (corrected on a per plot basis) with ± S.E. between 2001 10 m x 10 m SMZ plots (n=58) and non-SMZ plots (n=93) and between 2002 10 m x 10 m SMZ plots (n=66) and non-SMZ plots (n=153) for the 6 most common salamander species found, MeadWestvaco industrial forest, Randolph County, WV; an asterisk (*) above error bars indicates a significance at the 0.10 (from results of Student's t-tests) for that species. (Species are listed by their abbreviated scientific names; see Table 2.2 for list of names.)

CHAPTER 3: EFFECTS OF CLEARCUTS ON SALAMANDER POPULATIONS AND COMMUNITIES: PREHARVEST AND POSTHARVEST DATA

INTRODUCTION

Many studies have examined the effects of silviculture on amphibian diversity, relative abundance, and microclimate conditions. Examples of short-term negative effects of timber harvesting on terrestrial salamanders are well-documented (Blymer and McGinnes 1977, Pough et al. 1987, Bury 1983, Ash 1988, Petranka et al. 1993, Ash and Bruce 1994, Petranka et al. 1994, deMaynadier and Hunter 1995, Dupuis et al. 1995, Means et al. 1996, Mitchell et al. 1996, Ash 1997, Messere and Ducey 1998, Sattler and Reichenbach 1998, Herbeck and Larsen 1999, Harpole and Haas 1999, Bartman et al. 2001, Duguay and Wood 2002, Knapp et al. 2003). In 3 years of postharvest sampling, Harpole and Haas (1999) found that salamander relative abundance was reduced on sites that had been harvested using silvicultural techniques such as clearcut, shelterwood, group selection, and leavetree. Petranka et al. (1994) suggested that terrestrial salamanders could be eliminated altogether from mature forests that are clearcut. Herbeck and Larsen (1999) reported terrestrial plethodontid salamanders were reduced to very low numbers after intensive harvest on mature forest (>70 years old) probably due to decreased microhabitat availability. With similar findings, Duguay and Wood (2002) discovered lower salamander relative abundance in 15 year-old forests regenerating after timber harvest than in mature second-growth forests (>60 years old).

Recolonization rates, or recovery time of salamander communities after harvest, vary in recent research. Ash (1997), in the only longitudinal study to document recovery, reported a 4-year absence of the terrestrial salamander, *Plethodon jordani*, from clearcut forests after timber harvest. Ash (1988, 1997) estimated an overall recovery time of 20-24 years for salamander populations in clearcuts to regain preharvest population levels or levels equal to those on similar nonharvested areas. Other estimates are not as optimistic; Petranka et al. (1993), whose data were based on chronosequences, stated that a realistic time frame for salamander recolonization is 50-70 years. Similar to Petranka et al. (1993), Bonin (1991), in the abstract to his MS thesis, estimated recovery rates of 30-60 years for salamander populations in the eastern United States.

Key factors influencing recovery rates of salamander populations after timber harvest could be salamander community composition prior to harvest, the immediate and long-term fates of resident individuals, and whether these residents or those of adjacent forests are responsible for recolonizing clearcut areas over time (Ash 1988, Ford et al. 2002). Other factors influencing recolonization rates of terrestrial salamanders might be site characteristics such as elevation, aspect, site moisture, and their influence on microclimate conditions (Petranka et al. 1994, Harper and Guynn 1999), herbaceous plant communities, and the size of a harvest opening, or canopy gap (Diller and Wallace 1994, Ford et al. 1999). Edge effects of intensive timber harvest may penetrate as far as 25-40 m into surrounding forest, influencing the quality of microhabitat in these areas and possibly affecting recolonization rates (deMaynadier and Hunter 1998, DeGraaf and Yamasaki 2002). In their review paper, deMaynadier and Hunter (1995) proposed that long-term effects of timber harvesting on salamanders vary and may be mitigated if silvicultural practices minimize negative effects on microhabitat structure such as soil compaction, removal of coarse woody debris, removal of understory vegetation, and disturbance of the leaf litter layer.

OBJECTIVES

My first objective was to provide preharvest and postharvest baseline data on terrestrial salamander species richness, species diversity, relative abundance, and distribution in reference areas selected for clearcuts. My second objective was to use a similarity index to compare the 2 sampling techniques of constrained-area nighttime searches vs. daytime coverboard searches based on the proportion of common species captured.

STUDY SITES

As mentioned in Chapter 1, all study sites were located in the Allegheny Highlands of the central Appalachian Mountains, near Adolph, West Virginia, on MeadWestvaco industrial forest. Six of the 9 study sites were on the MeadWestvaco Wildlife and Ecosystem Research Forest (WERF), and the remaining 3 sites were on MeadWestvaco industrial forest ~4 mi to the north that was annexed for the ALEP. Near the center of all 9 forest compartments, reference areas of approximately 11.2 ha (28 ac) were selected to receive clearcuts and were delineated with a southeastern aspect; a list of UTMs to locate these reference areas are included in Appendix C.

These sites were chosen to serve as long-term monitoring areas to examine the effects of surrounding landscapes on salamander community structure, distribution, and recolonization rates in clearcuts. Clearcuts were scheduled for all 3 compartments in a replicate block in the same year. Reference areas on compartments 7, 8, and 9 (replicate block C) were harvested in the summer and fall of 2001. Reference areas on compartments 4, 5, and 6 (replicate block B) were harvested in the late summer of 2002. Reference areas on compartment 1, 2, and 3 (replicate block A) will be harvested in the late summer or fall of 2003 (see Table 1.1).

METHODS

We used nighttime area-constrained search techniques (Crump and Scott 1994) and daytime coverboard surveys (Fellers and Drost 1994) during the summers of 2001 and 2002. Sites for this objective included the reference cut locations near the center of each compartment. In these areas we examined preharvest relative abundance, species richness, species diversity, and spatial distribution on all 3 replicate blocks (9 compartments); only replicate block C was examined postharvest (compartments 7, 8, and 9).

Night Plots

For the night sampling technique, in each reference cut we established 30 m x 4 m plots (n=4) at least 50 m apart and at least 50 m from reference cut boundaries (Figure 3.1). We attempted to represent the entire area with approximately equally spaced plots. Sampling began shortly after dark in the rain or within several hours of a rain event while the forest floor and/or the surface leaf layer were still moist. Up to 4 technicians at a time crawled on hands and knees, side-by-side, traversing the plot to locate salamanders active in the leaf litter or on surface rocks, woody debris, herbaceous plants, or tree trunks. Our area-constrained searches were not time-constrained, but as a consequence of the time required to traverse the plot, crews searched each plot for approximately 40 minutes, sometimes more depending on the number of captures and the difficulty of negotiating the plot (i.e., moving through briar patches or over slash and large debris piles).

Each hand-captured individual was placed in a numbered, zipper-locking, plastic bag containing moist leaf litter, and the capture site was marked with a numbered pin flag for reference so that animals could be returned to the exact location of capture after they were processed. Captured salamanders were stored overnight in a cooler with reusable ice blocks. We used a cardboard layer between the ice blocks and the plastic bags to protect the salamanders that were on the bottom of the pile from direct contact with the ice.

At our field station the morning after a night sample, we collected morphological data for each salamander caught. We used scientific, dial calipers (+/- 0.03 mm accuracy) to measure snout-vent length (SVL) and total length (TL) to the nearest 1.0 mm for each salamander while it was still in the bag. Salamanders were weighed in a plastic tray on a battery-powered, electronic balance to the nearest 0.01 g, subtracting the weight of the tray. Salamanders were sexed when possible by observing visible secondary sex characteristics or by using a concentrated beam from a desktop fiber optics unit. For all light-bodied salamanders, transilluminating their bodies allowed us to determine the presence of eggs in gravid females or pigmented testes in males. When possible, 2 or more technicians counted yolked eggs in gravid females to reach a consensus on the minimum number of eggs present. All salamanders captured in a night sample were returned to their capture location within 12-16 hours.

Within a replicate block, 1 plot on all 3 compartments was sampled on a given night. I chose the order of compartment sampling within a replicate block at random, and all 3 blocks were represented once before any block was sampled repeatedly. The goal was to sample each compartment 4 times per year. I also chose which of the 4 plots we sampled within compartments randomly without replacement. This technique was used both for preharvest sampling and postharvest sampling.

From 6 June to 1 July 2001, we sampled a total of 12 plots once each, 4 plots each on compartments 7, 8, and 9 for 1 year of preharvest data. In the fall of 2001, clearcuts were implemented on these reference areas. From 13 May to 13 July 2002, we sampled a total of 36 plots once each, 4 plots each on compartments 7-9 for 1 year of postharvest data and 4 plots each on compartments 1-3 and 4-6 for 1 year of preharvest data (Appendix A).

Coverboards

The purpose of coverboard surveys was to examine distribution of salamanders within the reference cut before and after timber harvest. These data will also be used in future, long-term assessments of population and species recovery rates in relation to proximity of mature forest. From 12 August through 15 September 2001, we conducted coverboard surveys on the reference cuts of compartments 7 and 9 only. Because we did not obtain coverboards until mid-summer, compartment 8 was unavailable for coverboard sampling before the clearcut that was implemented in mid-summer instead of the fall. From 30 May through 1 August 2002, we conducted coverboard surveys on compartments 7-9 for postharvest data and on compartments 1-3 and 4-6 for preharvest data (Appendix A). In 2001 we used boards made of rough-cut yellow poplar (*Liriodendron tulipifera*), 5 x 25 x 90 cm in size. In 2002 we used boards made of untreated Eastern hemlock (*Tsuga canadensis*), 2.5 x 30 x 90 cm in size on compartments 1-3 and 4-6; the yellow poplar boards from compartments 7-9 in 2001 were used again on those compartments in 2002. Only one kind of board was used per compartment to ensure consistency; the type of wood used was based on availability at the start of each season.

We placed 6 coverboards per station (2 rows of 3 boards, spaced ~0.5 m apart) in a transect of 4 stations for 3 of the 4 sides of the reference cut, to total 3 transects, 12 stations, and 72 boards in all per compartment (Figure 3.2). All reference cuts were located off a road for easy access, so we chose the 3 sides not adjacent to the road for placing transects. Transects were located near the midpoint of each side and followed a compass bearing toward the reference cut center. For all transects on all compartments, coverboard station 1 was placed in mature forest 40-50 m outside the reference cut boundary. Station 2 was placed 5-10 m inside the boundary, station 3 was 40-50 m inside the boundary, and station 4 was ≥100 m inside the boundary (Figure 3.2).

Coverboards were installed after first clearing the ground below each board of all rocks, woody debris, and leaf litter so the boards were as flush to the ground as possible. Boards were then allowed to weather in place for approximately 3 weeks to 1 month prior to sampling. Sampling occurred in the morning 2-3 days after rain had moistened the soil underneath the boards and the surrounding leaf litter had dried, increasing the probability salamanders might use the boards as cover (Harpole 1996, Knapp 1999).

I randomly chose the sampling order for reference cuts within a block in 2001 because only 1 or 2 people conducted the survey. In 2002 we had 3 crews of 2 people working at the same time, each crew on 1 compartment, so surveys were completed simultaneously. The order for sampling coverboard transects within a compartment was randomly chosen for both years; however, for efficiency, coverboard stations were sampled in sequential order along each transect, starting at the edge and working in toward the center of the reference cut or starting from the center of the cut and working out toward the edge. We collected the same morphological data mentioned previously for night sampling for specimens found under coverboards. Salamanders were processed in the field and returned to the coverboard station immediately.

In 2002 we collected microclimate variables at coverboard stations to examine conditions at each station. On each day of sampling, I chose 1 coverboard transect in each compartment on which to collect soil temperatures. At all 4 stations on the chosen transect, we measured soil temperature in 2 random locations within 1 m outside the station and under 2 randomly chosen coverboards. We used Taylor^{TM} soil thermometers to take temperatures at depths of 2.5 cm and 10 cm at all 4 locations. We repeated this process until soil temperatures at all 3 coverboard transects in a compartment had been recorded over the summer. In the middle of each station, we also recorded % canopy cover in 4 cardinal directions using a spherical densiometer. A crew member stood in one spot and rotated to the north, south, east, and west, recording % canopy cover in each direction. We averaged those measurements to obtain an index of mean % canopy cover. We decided not to analyze soil temperature or canopy cover data here, as more thorough habitat data were available on the terrestrial plots (Chapter 2), but for long-term reference this information is available in Appendix D.

STATISTICAL ANALYSES

For most analyses, I did not pool captures across years but treated the years separately. For morphological and demographic analyses and summaries, I combined night plot and coverboard data to increase sample sizes for individual species, sexes, and age classes. In 2001 all coverboard and night plot sampling was done on preharvest reference areas, while 2002 coverboard and night plot sampling was done on preharvest and postharvest reference areas. For abundance analyses, the project goal was to study terrestrial amphibian communities, not individual species; therefore, the majority of abundance analyses on reference areas were completed using all species captured. I used a significance level of 0.10 and performed all analyses with SAS statistical software (SAS Institute 2002) or JMP statistical software (SAS Institute 2001).

Relative Abundance, Species Richness, and Species Diversity

For each year of sampling, I report relative abundance by species (including number of captures, escapes, and frog/toad encounters) pooled for all 4 night plot sampling efforts and all 3 coverboard sampling efforts for each compartment.

I used ANOVA with compartments as a blocking factor to examine differences in relative abundance between preharvest compartments and postharvest compartments across years for both night plot and coverboard data. I also used ANOVA to examine differences in relative abundance among coverboard stations preharvest to postharvest for pooled compartments. I used ANOVA to determine whether relative abundance at each coverboard station was significantly different preharvest to postharvest.

For 2001 and 2002 I reported all species found on night plots and in coverboard surveys and used data from both sampling techniques in analyses of species richness. Using Sorenson's coefficient of similarity (Krebs 1999), which can range from 0.00 to 1.00, and is based on the presence or absence of species and the number of species 2 sites have in common, I examined similarities across years for differences preharvest to postharvest.

Finally, I used Simpson's index (Krebs 1999) to calculate species diversity for all preharvest and postharvest compartments for night plot and coverboard data. Simpson's index can range from 0 to 1 and is the probability of choosing 2 individuals at random from a population that are from different species.

Population Characteristics

To determine age classes for captured and processed salamanders, I used the minimum SVLs (mm) I described in Chapter 2. For all demographic and morphological analyses and summaries, I combined coverboard and night plot data to increase sample sizes. When samples sizes were adequate (≥ 10), I used Student's t-tests to examine differences in preharvest and postharvest overall physical condition (mean M/SVL ratio) and preharvest and postharvest sex ratio and age class distribution.

I calculated the proportion of gravid females out of all light-bodied female salamanders processed, as an index of fertility. I determined the proportion of all processed salamanders with regenerating tails on compartments, which could indicate the level of predation and/or competition present within the salamander community.

Similarity Between Sampling Techniques

To determine the degree of similarity between the night plot and coverboard sampling techniques in characterizing relative abundance of each species on each compartment, I calculated proportions of individuals found with each technique for the 4 most common species for preharvest and postharvest data. Species included in this analysis were N. dusky salamander (*Desmognathus f. fuscus*), Allegheny Mt. dusky salamander (*Desmognathus ochropheus*), redback salamander (*Plethodon cinereus*), and slimy salamander (*Plethodon g. glutinosus*). I analyzed those data using Pianka's index of symmetry (Krebs 1999) to generate percent similarities (ranging from 0% to 100%) between the 2 techniques on each compartment.

RESULTS

Relative Abundance, Species Richness, and Species Diversity

No frogs or toads were captured at any preharvest or postharvest coverboard stations. We captured 6 salamander species (94 individuals) from 12 August-15 September 2001 during preharvest sampling on compartments 7 and 9. We found 5 salamander species (44 individuals) during postharvest coverboard sampling on compartments 7-9. Seven salamander species (47 individuals) were captured on compartments 1-3, and 5 salamander species (103 individuals) were encountered on compartments 4-6 during preharvest sampling from 30 May-1 August 2002 (Table 3.1). From 6 June-1 July 2001, we found 11 amphibian species (265 individuals) on preharvest night plots on compartments 7-9. We observed 9 amphibian species (141 individuals) on postharvest night plots on compartments 7-9. On compartments 1-3, we encountered 10 species (163 individuals), and on compartments 4-6, we found 9 species (162 individuals) on preharvest night plots from 13 May-13 July 2002 (Table 3.2). From preharvest to postharvest on compartments 7-9, only 1 species (E. red-spotted newt) at coverboards and 1 species (N. two-lined salamander) on night plots dropped off the species list altogether, while 1 species (N. spring salamander) was added postharvest on night plots.

An ANOVA, with compartments as a blocking factor, showed that mean coverboard captures decreased significantly from preharvest to postharvest for compartments 7 and 9 (p=0.0172, F=7.45, df=13). Likewise, an ANOVA, with compartments as a blocking factor, revealed a significant decrease in total captures on night plots for compartments 7-9, (p=0.0118, F=7.68, df=20) (Table 3.3, Figure 3.3).

For compartments 7 and 9, ANOVA showed that station 2 (located 5-10 m inside clearcut) (p=0.0163, F=1521.00, df=1) and station 3 (located 40-50 m inside clearcut) (p=0.0193, F=1089.00, df=1) had significantly fewer captures postharvest. Station 1 (located 40-50 m outside clearcut in mature forest) (p=0.3889, F=2.04, df=1) and station 4 (located ≥100 m inside clearcut) (p=0.500, F=1.00, df=1) showed no significant differences between preharvest and postharvest mean captures (Table 3.4, Figure 3.4). The fact that no differences were detected for station 4 could be related to our failure to capture salamanders at any of the station 4 coverboards on compartment 9 in either year, possibly an indication that habitat quality was poorer near the middle of this reference cut even before clearcutting began. Figures 3.5-3.6 display mean capture data from coverboard and night plot preharvest sampling on compartments 1-3 and 4-6.

I used Sorenson's coefficient (Krebs 1999) to examine similarity in presence/absence of species between compartments. Preharvest coverboard data revealed a similarity of 0.91 between compartments 7 and 9, while postharvest similarities for compartments 7-9 averaged 0.70. Preharvest night plot data on compartments 7-9 had a mean similarity of 0.75, compared to 0.65 postharvest. Preharvest compartments 1-3 had similarities that averaged 0.55 based on coverboard data and 0.58 based on night plot data; preharvest compartments 4-6 had a mean similarity of 0.89 from coverboard data and 0.80 from night plot data (Table 3.5). Results suggest that generally preharvest compartments within the same replicate block tended to be more similar with each other than with compartments in other blocks (with the exception of compartment 3) and that pairs of compartments decreased in similarity from preharvest to postharvest.

I calculated Simpson's index of diversity (Krebs 1999) for night plot and coverboard data on all preharvest and postharvest compartments. For coverboard data, diversity decreased on compartments 7 and 9 from preharvest to postharvest; diversity decreased for night plot data on compartments 7 and 9 and slightly increased on compartment 8 (Table 3.6). . Diversity on preharvest compartments 1-3 averaged 0.62 for coverboards and 0.54 for night plots, while diversity on preharvest compartments 4-6 averaged 0.66 for coverboards and 0.72 for night plots (Table 3.6).

Population Characteristics

MORPHOLOGICAL CHARACTERISTICS

Morphological data for all preharvest and postharvest compartments are given in Table 3.7. For female N. dusky salamanders (p=0.8942, t=0.13, df=20), female Allegheny Mt. dusky salamanders (p=0.1678, t=-1.41, df=39), male Allegheny Mt. dusky salamanders (p=0.5250, t=0.64, df=50), and juvenile redback salamanders (p=0.6813, t=0.41, df=52) on compartments 7-9, Student's t-tests showed no significant differences between preharvest and postharvest mean M/SVL (g/mm) ratio. Juvenile Allegheny Mt. dusky salamanders (p=0.0272, t=-2.25, df=76) and juvenile slimy salamanders (p=0.0898, t=-1.72, df=65) showed significant increases in mean M/SVL (g/mm) ratio from preharvest to postharvest (Table 3.8).

SEX RATIO AND AGE CLASS DISTRIBUTION

I did not statistically analyze differences in sex ratio or age class distribution from preharvest to postharvest on compartments 7-9 using coverboard data because we did not conduct coverboard surveys in the same season each year. Comparing demographics across years could introduce a temporal bias into the analysis because seasonal changes in male and female behavior could affect the probability of being captured under coverboards (i.e., females laying and brooding clutches in late spring/early summer) (Duellman and Trueb 1986, Zug 1993, Petranka 1998). For night plot data only, Chi-square analyses resulted in no significant differences in adult sex ratio (p=0.4677, X^2=0.527, df=112) or age class distribution (p=0.5031, X^2=0.448, df=329) between compartments 7-9 preharvest to postharvest (Table 3.9). Table 3.10 shows a summary of sex ratio and age class distribution for all preharvest and postharvest compartments.

FERTILITY AND FECUNDITY

Out of 60 light-bodied female salamanders captured and processed on preharvest compartments 7-9 night plots and coverboards, 27 were gravid (45%). Nine out of 39 (23%) were gravid on postharvest compartments 7-9. Nine out of 39 (23%) were gravid on preharvest compartments 1-3, and 8 out of 73 (11%) were gravid on preharvest compartments 4-6 (Table 3.11).

During night plot sampling on preharvest compartment 7 (14 June 2001), we found a loose cluster of salamander eggs, that appeared to have been disturbed, on leaf litter next to a log. We captured a juvenile Allegheny Mt. dusky on the log but no brooding females. We did not record a count of eggs or a description of eggs in the nest. While sampling coverboards on preharvest compartment 6 (19 June 2002), we encountered a scattered nest of 9 white eggs next to station 4 coverboards (located $\geq$100 m inside clearcut); an adult female Allegheny Mt. dusky salamander was captured at this station during this survey.

REGENERATING TAILS

Sixty-three out of 320 captured and processed salamanders (20%) on preharvest compartments 7-9 had missing or regenerating tails. On postharvest compartments 7-9, 28 out of 144 (19%) captured and processed salamanders had missing or regenerating tails**.** Finally, on preharvest compartments 1-3, we discovered 12 out of 166 (7%) captured and processed salamanders with missing or regenerating tails, and on preharvest compartments 4-6 we discovered 24 out of 245 (10%) (Appendix B).

Similarity Between Sampling Techniques

I used Pianka's index (Krebs 1999) to compare results between night plot and coverboard sampling techniques based on proportions of individuals from the 4 most common species observed with each method (species used in analysis included *Desmognathus f. fuscus, Desmognathus ochropheus, Plethodon cinereus,* and *Plethodon g. glutinosus*) (Table 3.12). Results for preharvest compartments 7 and 9, showed a high level of symmetry between night plot and coverboard captures on both compartments (mean=85%); compartment 8 was not included in this analysis because preharvest coverboard data were not available. Postharvest compartments 7-9 had a slightly lower mean similarity of 75%. The 2 techniques on average were 83% similar on preharvest compartments 1-3 and 82% similar on preharvest compartments 4-6 (Table 3.12).

DISCUSSION

Relative Abundance, Species Richness, and Species Diversity

Other than providing preharvest baseline data, the main outcomes of this study were that species richness and relative abundance decreased in year 1 postharvest for coverboard and night plot sampling on compartments 7 and 9. Sorenson's coefficient showed that communities in neighboring compartments became less similar to each other postharvest than they were preharvest, suggesting that species that persist after harvest are a random subset of the community, not a select group that are particularly resilient to disturbance. Overall, species diversity showed little change from preharvest to postharvest. Relative abundance decreased significantly by 64% for compartment 7 and 47% for compartment 9. For night plot sampling, species richness declined slightly in year 1 postharvest. Relative abundance for all species at coverboard stations decreased significantly by 26% preharvest to year 1 postharvest for station 1 (40-50 m outside reference cut boundary) and by 73% for station 3 (40-50 m inside reference cut boundary). Based on previous studies showing salamander population declines in clearcuts, we expected to see relative abundance decline more in stations 2-4 than in station 1. The decrease at station 1 could simply be a factor of the prolonged drought in 2002 where relative abundance throughout the forest decreased, or clearcut edge effects could have penetrated that far into mature forest (40-50 m). It is possible that no effects were seen at station 2 (5-10 m inside reference cut boundary) in year 1 of postharvest sampling because of its proximity to mature forest and the reference cut boundary where surviving salamanders from the interior of the cut should be migrating toward. It is likely no changes were seen for station 4, compartments pooled, because compartment 9 had no captures at station 4 on any of the 3 transects preharvest or postharvest.

Combining coverboard sampling and night plots, replicate block A (compartments 1-3), which is the property outside the WERF annexed for this landscape study, yielded the lowest number of captures and some of the lowest species diversity values. These findings could be a result of poorer habitat quality on this property; however, as presented in Table 1.1, compartments 1-3 were relatively similar in stand age and stand type to all other compartments. These 3 compartments were at a slightly lower elevation (~2700 ft vs. ~3200 ft) and have a lower mean site index (~68 vs. ~ 73), although these differences are not large.

The differences we found in relative abundance preharvest to year 1 postharvest are not well supported in the literature. Most studies that have investigated effects of canopy removal on salamander populations (e.g., Harpole and Haas 1999, Knapp et al. 2003), and reviews of silviculture effects on salamanders (e.g., DeMaynadier and Hunter 1995) indicate that populations do not crash or even drop significantly or until years 2-5 postharvest. Our results could indicate a more dramatic scenario unfolding on our particular sites pertaining to the harshness of microclimate conditions immediately after a clearcut. Other factors could be a year effect of poor climate and weather conditions in 2002, year 1 postharvest (Bartman et al. 2001). As discussed in Chapter 2, sampling in 2002 was completed in the third year of a substantial drought in the southeast and mid-Atlantic states which would have changed environmental conditions, regardless of silvicultural activities, as was seen on all uncut sites throughout the forest as well as in all station 1 coverboards which were located in uncut, mature forest.

Population Characteristics

Analyses of mean morphological characteristics for the most common species and sexes found on preharvest and postharvest night plots showed no definite trends that would suggest that in the first year after a clearcut, salamanders are in poorer physical condition. Juvenile redback salamanders and adult male Allegheny Mt. dusky salamanders displayed a slight drop in M/SVL ratio (g/mm) from preharvest to postharvest. Female N. dusky salamander M/SVL ratio remained the same each year. Juvenile slimy salamanders and juvenile Allegheny Mt. dusky salamanders showed significant increases in M/SVL ratio, while adult female Allegheny Mt. dusky salamander M/SVL ratio also increased but not significantly. The apparent size increase in some juveniles and adults could result from a differential loss of smaller, more vulnerable individuals after clearcutting and may explain why populations seemed to increase in physical condition postharvest.

These increases in size seem counterintuitive because canopy removal should introduce added physical and physiological stress to salamanders from increased temperatures (and thus increased caloric requirements), decreased ground moisture, and decreased foraging opportunities (Harpole 1996). This discrepancy could also support the claim that M/SVL ratio, as well as other morphological characteristics, are too variable to be solid predictors of overall salamander health and body condition (Harpole 1996). My results are similar to those of Chazal and Niewiarowski (1998) who showed that immediately after clearcuts (5-6 mos.), mole salamanders (*Ambystoma talpoideum*) showed no differences in mass or TL.

Although I presented summaries and comparisons of preharvest and postharvest fertility of females, sample sizes were too small to make any claims about the effects of clearcutting on reproduction. The differences and decreases in fecundity and fertility I reported could indicate inherent variability within the population for certain species or could indicate inaccuracies or biases in sexing techniques in 2002.

Juvenile and male Allegheny Mt. dusky salamanders and juvenile slimy salamanders displayed increases in the percentage with missing or regenerating tails from preharvest to postharvest. The increases shown could indicate higher rates of attempted predation and inter and intraspecific competition for high quality territories and foraging opportunities as microhabitat and microclimate conditions became degraded in the first year after clearcuts.

The main difference (although statistically insignificant) in preharvest and year 1 postharvest sex ratio and age class distribution for both coverboards and night plots was an overall increase in the proportion of adults captured. The decrease in the number of juvenile salamanders observed in coverboard and night plot surveys could indicate the beginning stages of increased stress on that age class because of the sudden removal of canopy and rapidly degrading microclimate conditions. With this scenario, smaller animals may have been more likely to die, leaving larger animals to be sampled (Ash 1997, Knapp 1999, Knapp et al. 2003). Overall, the sex ratio remained constant from preharvest to postharvest at approximately 1:1, males to females. Only compartment 8 showed a dramatic increase in the number of females preharvest to postharvest. It is possible that more females were observed in year 1 postharvest on compartment 8 because fewer could afford to lay clutches and/or remain hidden guarding nests when their own health and body condition was at jeopardy from the harsh habitat conditions left on this compartment after the clearcut, which was implemented 3-4 months earlier in 2001 than cuts on compartments 7 and 9. Theoretically, conditions could have worsened on compartment 8 more dramatically than on compartments 7 and 9 by the time we began postharvest sampling in May of 2002. Poorer conditions on compartment 8 along with increasing negative effects the prolonged drought had on microhabitat and microclimate also could have forced adult females to spend more time foraging on the surface than they normally would during the breeding and nesting season. Another reason for the increased number of females in 2002 could be that we started conducting night plot sampling 2-3 weeks earlier (beginning in mid-late May) than in 2001 and did not have preharvest coverboard data for compartment 8 to form a basis of comparison. Sampling earlier in the season could have allowed us to capture more females prior to their nesting activities in mid-late summer.

Similarity Indices

The main result from Pianka's index was that the coverboard sampling technique and the night plot sampling technique were highly correlated for both preharvest data and 2002 preharvest and postharvest data across compartments (mean=81%) in terms of the proportions of captures for each of the 4 common species used in analyses. Although, for other projects in the future, the high level of symmetry between the 2 techniques could justify researchers choosing one kind of survey over the other to save financial and personnel resources, it is not recommended that a sampling technique be dropped for this particular study. Since one of the main purposes of coverboard surveys is to examine community distribution throughout the reference cut in proximity to mature forest, that technique should be kept in future studies. One advantage of night plot sampling, besides the high capture rates, is that sex ratio and age class distribution, particularly of the plethodontid community, might be represented more accurately than if researchers used coverboards only. For example, based on my results, adult slimy salamanders were highly underrepresented in coverboard surveys, possibly due to their large body size, but adult slimy salamanders were the most abundant individuals in night plot surveys, combining both years.

Considerations for Future Research

As coverboard and night plot sampling are continued over a long period, it will become more evident if any of my speculations or theorized population trends have merit or if the results I observed were only year or site effects, having more to do with abiotic factors (i.e., climate, drought) than declining microhabitat quality. As suggested in the literature, years 2-5 postharvest should display an outright population crash. Future researchers should monitor how sex ratio, age class distribution, and morphological characteristics change over time and which sex or age class, as well as which species, fares better as conditions worsen then gradually improve over time.

Community distribution and composition throughout the reference cuts will also be interesting as future studies track recolonization rates in relation to proximity of mature forest. Intuitively, one would think that coverboard station 1 (40-50 m outside clearcut in mature forest) and possibly station 2 (5-10 m inside clearcut) should show the highest and most stable levels of relative abundance in the upcoming years since they are located within or close to mature forest. Long-term coverboard sampling should help document the rate of recolonization as salamander populations recover after clearcuts.

Future researchers should also consider measuring and monitoring how stand level habitat, microhabitat, and microclimate characteristics differ over time as clearcuts start to regenerate and habitat conditions change. For example, temperature data loggers positioned under coverboards could be useful for comparing microclimate conditions at each station. Monitoring habitat at coverboard stations could prove helpful in studying relationships between recolonization rates and habitat characteristics at each of the coverboard station distances away from adjacent mature forest, since approximately the same transects will be used in subsequent years.

My goal in the initial phase of the ALEP project was to present baseline information on compartments 1-3 (replicate block A), 4-6 (replicate block B), and 7-9 (replicate block C) composing the study sites in the ALEP. As this long-term study progresses, future researchers will be able to conduct more meaningful analyses to examine differences in species richness, species diversity, relative abundance, demographics, morphology, and community distribution among the 3 replicate blocks, the 3 harvest treatment blocks, and the compartments within these blocks.

CHAPTER 3

TABLES

Table 3.1. Summary of 2001and 2002 salamander species richness and relative abundance from 3 preharvest coverboard surveys on compartments 7 and 9 (12 August-15 September 2001), 3 postharvest coverboard surveys on compartments 7-9 (30 May-1 August 2002), and 3 preharvest coverboard surveys on compartments 1-3 and 4-6 (30 May-1 August 2002), all sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. Total observations of each species are reported after species name and reflect captured and escaped individuals; the mean (± S.E.) number observed per compartment for each replicate block is presented immediately following total observations.

SPECIES	SCIENTIFIC NAME	2001 BDS PRE C 7, 9	**MEAN OBS PER COMP**	2002 BDS POST C 7-9	**MEAN OBS PER COMP**	2002 BDS PRE C 1-3	**MEAN OBS PER COMP**	2002 BDS PRE C 4-6	**MEAN OBS PER COMP**
Allegheny Mt. dusky salamander	*Desmognathus ochropheus*	49	**24.5** (±5.50)	24	**8.0** (±3.61)	22	**7.3** (±6.36)	36	**12.0** (±5.51)
Appalachian seal salamander	*Desmognathus m. monticola*	7	**3.5** (±0.50)	1	**0.3** (±0.33)	0	**0.0** (±0.00)	1	**0.3** (±0.33)
E. red-spotted newt (eft)	*Notophthalmus v. viridescens*	1	**0.5** (±0.50)	0	**0.0** (±0.00)	1	**0.3** (±0.33)	0	**0.0** (±0.00)
N. dusky salamander	*Desmognathus f. fuscus*	8	**4.0** (±2.00)	11	**3.7** (±0.67)	6	**2.0** (±1.53)	14	**4.7** (±2.33)
N. two-lined Salamander	*Eurycea b. bislineata*	0	**0.0** (±0.00)	0	**0.0** (±0.00)	2	**0.7** (±0.67)	0	**0.0** (±0.00)
Redback salamander	*Plethodon cinereus*	22	**11.0** (±4.00)	5	**1.7** (±1.20)	5	**1.7** (±0.89)	40	**13.3** (±4.41)
Slimy salamander	*Plethodon g. glutinosus*	7	**3.5** (±2.50)	1	**0.3** (±0.33)	10	**3.3** (±0.83)	11	**1.8** (±0.33)
(unidentified *Desmognathus*)	*Desmognathus* spp.	0	**0.0** (±0.00)	2	**0.7** (±0.33)	0	**0.0** (±0.00)	1	**0.3** (±0.33)
Wehrle's salamander	*Plethodon wehrlei*	0	**0.0** (±0.00)	0	**0.0** (±0.00)	1	**0.3** (±0.33)	0	**0.0** (±0.00)
TOTALS		**94**		**44**		**47**		**103**	

Table 3.2. Summary of 2001and 2002 amphibian species richness and relative abundance from 4 preharvest night plot surveys on compartments 7-9 (6 June-1July 2001), 4 postharvest night plot surveys on compartments 7-9 (13 May-13 July 2002), and 4 preharvest night plot surveys on compartments 1-3 and 4-6 (13 May-13 July 2002), all sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. Total observations of each species are reported after species name and reflect captured and escaped individuals; the mean (± S.E.) number observed per compartment for each replicate block is presented immediately following total observations.

SPECIES	SCIENTIFIC NAME	2001 PLTS PRE C 7, 9	**MEAN OBS PER COMP**	2002 PLTS POST C 7-9	**MEAN OBS PER COMP**	2002 PLTS PRE C 1-3	**MEAN OBS PER COMP**	2002 PLTS PRE C 4-6	**MEAN OBS PER COMP**
Allegheny Mt. dusky salamander	*Desmognathus ochropheus*	69	**23.0** (±6.81)	46	**15.3** (±4.91)	74	**24.7** (±14.05)	45	**15.0** (±3.61)
American toad	*Bufo. americanus*	1	**0.3** (±0.33)	1	**0.3** (±0.33)	4	**1.3** (±1.33)	0	**0.0** (±0.00)
Appalachian seal salamander	*Desmognathus m. monticola*	16	**5.3** (±4.84)	8	**2.7** (±2.67)	4	**1.3** (±1.33)	2	**0.7** (±0.67)
E. red-spotted newt (eft)	*Notophthalmus v. viridescens*	7	**2.3** (±0.88)	2	**0.7** (±0.33)	1	**0.3** (±0.33)	0	**0.0** (±0.00)
Fowler's toad	*Bufo woodhousii. fowleri*	0	**0.0** (±0.00)	0	**0.0** (±0.00)	1	**0.3** (±0.53)	0	**0.0** (±0.00)
N. dusky salamander	*Desmognathus f. fuscus*	29	**9.7** (±2.60)	8	**2.7** (±1.45)	15	**5.0** (±5.00)	6	**2.0** (±0.00)
N. spring salamander	*Gyrinophilus p.. porphyriticus*	1	**0.3** (±0.33)	1	**0.3** (±0.67)	0	**0.0** (±0.00)	1	**0.3** (±0.33)
N. two-lined Salamander	*Eurycea b. bislineata*	5	**1.7** (±1.67)	0	**0.0** (±0.00)	0	**0.0** (±0.00)	0	**0.0** (±0.00)
Redback salamander	*Plethodon cinereus*	57	**19.0** (±7.00)	20	**6.7** (±0.88)	9	**3.0** (±1.53)	32	**10.7** (±3.18)
Slimy salamander	*Plethodon g. glutinosus*	72	**24.0** (±0.33)	36	**12.0** (±1.86)	32	**10.7** (±4.18)	56	**18.7** (±1.86)
Spring peeper	*Pseudacris crucifer*	0	**0.0** (±0.00)	0	**0.0** (±0.00)	1	**0.3** (±0.83)	2	**0.7** (±0.33)
(unidentified *Desmognathus*)	*Desmognathus* spp.	4	**1.3** (±0.88)	18	**6.0** (±2.08)	20	**6.7** (±6.67)	6	**2.0** (±1.53)
Wehrle's salamander	*Plethodon wehrlei*	1	**0.3** (±0.33)	1	**0.3** (±0.33)	2	**0.7** (±0.67)	11	**3.7** (±1.45)
Wood frog	*Rana sylvatica*	3	**1.0** (±0.58)	0	**0.0** (±0.00)	0	**0.0** (±0.00)	1	**0.3** (±0.33)
TOTALS		**265**		**141**		**163**		**162**	

Table 3.3. Results from analysis of variance (with compartments as a blocking factor) to examine the difference in relative abundance between preharvest (12 August- 15 September 2001) and postharvest (30 May-1 August 2002) coverboard sampling and between preharvest (6 June-1 July 2001) and postharvest (13 May-13 July 2002) night plot sampling on compartments 7-9, MeadWestvaco industrial forest, Randolph County, WV; preharvest coverboard data for compartment 8 were not available. (Coverboard relative abundance includes mean captures per station (all sampling efforts pooled), and night plot relative abundance includes total captures per plot).

	COVERBOARDS				NIGHT PLOTS			
SOURCE	*df*	MS	F	p	*df*	MS	F	p
Treatment	1	24.26	7.45	0.0172	1	630.38	7.68	0.0118
Compartment	1	12.78	3.92	0.0692	2	41.38	0.50	0.6115
Error	13	3.26			20	82.08		

Table 3.4. Results from analysis of variance (with compartment as a blocking factor) to examine the difference in mean captures between preharvest (12 August- 15 September 2001) and postharvest (30 May-1 August 2002) coverboards at stations 1-4, on compartments 7 and 9 (preharvest data for compartment 8 were not available), MeadWestvaco industrial forest, Randolph County, WV; (station 1=40-50 m outside clearcut, station 2=5-10 m inside clearcut, station 3=40-50 m inside clearcut, station 4=$\geq$100 m inside clearcut).

SOURCE	*df*	MS	F	p
		Station 1		
Treatment	1	1.00	2.04	0.3888
Compartment	1	5.29	10.80	0.1881
Error	1	0.49		
		Station 2		
Treatment	1	34.22	1521.00	0.0163
Compartment	1	1.32	58.78	0.0826
Error	1	0.02		
		Station 3		
Treatment	1	2.72	1089.00	0.0193
Compartment	1	1.82	729.00	0.0236
Error	1	0.00		
		Station 4		
Treatment	1	1.82	1.00	0.5000
Compartment	1	5.52	3.03	0.3320
Error	1	1.82		

Table 3.5. Results from Sorenson's coefficient (Krebs 1999) to compare species richness, or species presence/absence, among compartments 7-9 for 3 preharvest and postharvest coverboard surveys per compartment (12 August-15 September 2001, 30 May-1 August 2002) and for 4 night plot surveys per compartment (6 June-1 July 2001, 13 May-13 July 2002), and among compartments 1-3 and 4-6 for 3 preharvest coverboard surveys per compartment (30 May-1 August 2002) and 4 preharvest night plot surveys per compartment (13 May-13 July 2002), MeadWestvaco industrial forest, Randolph County, WV; preharvest coverboard data for compartment 8 were not available.

COMPARTMENT PAIR	PREHARVEST COVERBOARDS	POSTHARVEST COVERBOARDS	PREHARVEST NIGHT PLOTS	POSTHARVEST NIGHT PLOTS
C1 & C2	0.75	N/A	0.46	N/A
C1 & C3	0.44	N/A	0.67	N/A
C2 & C3	0.43	N/A	0.60	N/A
C4 & C5	0.89	N/A	0.77	N/A
C4 & C6	0.89	N/A	0.77	N/A
C5 & C6	0.89	N/A	0.86	N/A
C7 & C8	N/A	0.75	0.86	0.73
C7 & C9	0.91	0.67	0.71	0.67
C8 & C9	N/A	0.67	0.67	0.55

Table 3.6. Results from Simpson's index of diversity (Krebs 1999) from coverboard and night plot sampling for preharvest compartments 7-9 (6 June-1 July 2001, 12 August-15 September 2001), postharvest compartments 7-9 (13 May-13 July 2002, 30 May-1 August 2002), and preharvest compartments 1-3 and 4-6 (13 May-13 July 2002, 30 May-1 August 2002), MeadWestvaco industrial forest, Randolph County, WV; values reflect the probability of capturing 2 individuals at random that are different species. (No preharvest coverboard data were available for compartment 8, and escaped/unidentified *Desmognathus* spp. were not included in analysis.)

COMPARTMENT	COVERBOARDS	NIGHT PLOTS
	Preharvest	
7	0.674	0.798
8	N/A	0.688
9	0.601	0.768
	Postharvest	
7	0.573	0.723
8	0.688	0.698
9	0.442	0.724
	Preharvest	
1	0.560	0.552
2	0.571	0.732
3	0.719	0.322
	Preharvest	
4	0.691	0.697
5	0.669	0.722
6	0.606	0.736

Table 3.7. Summary of preharvest and postharvest mean morphological characteristics (±S.E.) by species and sex for all captured and processed salamanders (where n≥10) found on preharvest compartments 1-3, 4-6, and 7-9 (6 June-1 July 2001, 12 August-15 September 2001, 13 May-13 July 2002, 30 May-1 August 2002) and postharvest compartments 7-9 (13 May-13 July 2002, 30 May-1 August 2002), all night plot and coverboard sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. (Preharvest coverboard data were not available for compartment 8.)

COMPARTMENTS 1-3

SPECIES	SEX	PRE N	POST N	PRE SVL (cm)	POST SVL (cm)	PRE TL (cm)	POST TL (cm)	PRE MASS (g)	POST MASS (g)	PRE M/SVL RATIO (g/mm)	POST M/SVL RATIO (g/mm)
Desmognathus ochropheus	F	21	N/A	35 (±0.65)		68 (±1.39)		0.74 (±0.05)		0.021 (±0.001)	
	M	22	N/A	39 (±0.83)		76 (±2.09)		1.08 (±0.06)		0.028 (±0.001)	
	J	42	N/A	24 (±0.83)		44 (±1.98)		0.28 (±0.02)		0.011 (±0.001)	
Desmognathus f. fuscus	F	11	N/A	36 (±1.28)		68 (±3.30)		0.84 (±0.08)		0.023 (±0.002)	
Plethodon g. glutinosus	J	24	N/A	34 (±1.90)		61 (±3.96)		0.91 (±0.15)		0.024 (±0.003)	

COMPARTMENTS 4-6

SPECIES	SEX	PRE N	POST N	PRE SVL (cm)	POST SVL (cm)	PRE TL (cm)	POST TL (cm)	PRE MASS (g)	POST MASS (g)	PRE M/SVL RATIO (g/mm)	POST M/SVL RATIO (g/mm)
Desmognathus ochropheus	F	28	N/A	35 (±0.69)		65 (±1.03)		0.74 (±0.03)		0.021 (±0.001)	
	M	22	N/A	37 (±0.66)		67 (±1.99)		0.89 (±0.04)		0.024 (±0.001)	
	J	29	N/A	24 (±0.99)		46 (±2.22)		0.32 (±0.03)		0.013 (±0.001)	
Plethodon cinereus	F	27	N/A	37 (±0.48)		59 (±2.63)		0.70 (±0.02)		0.019 (±0.001)	
	M	10	N/A	37 (±1.00)		65 (±1.84)		0.74 (±0.04)		0.020 (±0.001)	
	J	33	N/A	27 (±0.84)		47 (±1.50)		0.36 (±0.03)		0.013 (±0.001)	
Plethodon g. glutinosus	F	11	N/A	64 (±1.32)		121 (±5.75)		5.44 (±0.41)		0.084 (±0.006)	
	J	42	N/A	31 (±2.07)		57 (±4.56)		1.07 (±0.20)		0.025 (±0.004)	
Plethodon wehrlei	J	10	N/A	45 (±3.90)		90 (±11.44)		2.00 (±0.39)		0.042 (±0.006)	

SPECIES	SEX	PRE N	POST N	PRE SVL (cm)	POST SVL (cm)	PRE TL (cm)	POST TL (cm)	PRE MASS (g)	POST MASS (g)	PRE M/SVL RATIO (g/mm)	POST M/SVL RATIO (g/mm)
COMPARTMENTS 7-9											
Desmognathus ochropheus	F	26	16	33 (±0.52)	34 (±0.02)	61 (±1.55)	62 (±1.44)	0.66 (±0.01)	0.89 (±0.18)	0.020 (±0.001)	0.026 (±0.006)
	M	30	24	36 (±0.63)	35 (±0.88)	65 (±1.89)	63 (±2.17)	0.84 (±0.05)	0.78 (±0.05)	0.023 (±0.001)	0.022 (±0.001)
	J	54	23	24 (±0.45)	26 (±0.67)	45 (±1.19)	48 (±1.88)	0.30 (±0.01)	0.36 (±0.03)	0.012 (±0.000)	0.014 (±0.001)
Desmognathus f. fuscus	F	11	11	34 (±0.92)	37 (±1.24)	66 (±1.64)	70 (±1.53)	0.76 (±0.04)	0.82 (±0.12)	0.022 (±0.001)	0.022 (±0.003)
Plethodon cinereus	J	39	15	28 (±0.63)	27 (±1.42)	50 (±1.42)	45 (±2.64)	0.37 (±0.02)	0.33 (±0.04)	0.013 (±0.001)	0.012 (±0.001)
Plethodon g. glutinosus	J	48	19	30 (±1.01)	32 (±2.74)	54 (±2.09)	60 (±5.74)	0.63 (±0.06)	0.95 (±0.22)	0.019 (±0.001)	0.025 (+0.004)

Table 3.8. Results from Student's t-test analysis of the difference in mass/snout-vent length ratio (g/mm), an index of overall health and physical condition, for all captured and processed salamanders (where n≥10) on preharvest compartments 7-9 vs. postharvest compartments 7-9, 4 night plot and 3 coverboard sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. Preharvest sampling occurred 6 June-1 July 2001 and 12 August-15 September 2001; postharvest sampling occurred 13 May-13 July and 30 May-1 August 2002. (No preharvest coverboard data were available for compartment 8.)

SPECIES AND SEX	MEAN PRE M/SVL RATIO (g/mm)	MEAN POST M/SVL RATIO (g/mm)	t	*df*	p
Desmognathus f. fuscus (females)	0.022 (±0.001)	0.022 (±0.003)	0.13	20	0.8942
Desmognathus ochropheus (females)	0.020 (±0.001)	0.026 (±0.006)	-1.41	39	0.1678
Desmognathus ochropheus (males)	0.023 (±0.001)	0.022 (±0.001)	0.64	50	0.5250
Desmognathus ochropheus (juveniles)	0.012 (±0.000)	0.014 (±0.001)	-2.25	76	0.0272
Plethodon cinereus (juveniles)	0.013 (±0.001)	0.012 (±0.001)	0.41	52	0.6813
Plethodon g. glutinosus (juveniles)	0.019 (±0.001)	0.025 (±0.004)	-1.72	65	0.0898

Table 3.9. Results from Chi-square analysis of the difference in salamander sex ratio (males vs. females) and age class distribution (juveniles vs. adults) on preharvest compartments 7-9 vs. postharvest compartments 7-9, all night plot sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. Preharvest night plot sampling occurred 6 June-1 July 2001, and postharvest night plot sampling occurred 13 May-13 July 2002.

	MALES	FEMALES	JUVENILES	ADULTS	X^2	*df*	p
PRE	53%(39/73)	47%(34/73)					
POST	43%(19/41)	54%(22/41)					
					0.527	112	0.4677
PRE			57%(129/227)	43%(98/227)			
POST			53%(55/104)	47%(49/104)			
					0.448	329	0.5031

Table 3.10. Summary of preharvest (6 June-1 July 2001, 12 August-15 September 2001, 13 May-13 July 2002, 30 May-1 August 2002) sex ratio and age class distribution on compartments 1-3, 4-6, and 7-9 and postharvest (13 May-13 July 2002, 30 May-1 August 2002) sex ratio and age class distribution on compartments 7-9, for all captured and processed salamanders, all night plot and coverboard sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV. (Preharvest coverboard data for compartment 8 were not available.)

COMPARTMENT	PREHARVEST MALE : FEMALE	POSTHARVEST MALE : FEMALE	PREHARVEST JUVENILE : ADULT	POSTHARVEST JUVENILE : ADULT
1	1 : 1.45 (n=22) (n=32)	N/A	1 : 1.15 (n=47) (n=54)	N/A
2	1 : 1.14 (n=7) (n=8)	N/A	1 : 0.68 (n=22) (n=15)	N/A
3	1 : 1.50 (n=4) (n=6)	N/A	1 : 0.56 (n=18) (n=10)	N/A
4	1 : 1.38 (n=8) (n=11)	N/A	1 : 0.45 (n=42) (n=19)	N/A
5	1 : 1.41 (n=17) (n=24)	N/A	1 : 1.17 (n=35) (n=41)	N/A
6	1 : 1.86 (n=21) (n=39)	N/A	1 : 1.25 (n=48) (n=60)	N/A
7	1 : 0.96 (n=61) (n=55)	1 : 0.59 (n=78) (n=46)	1 : 1.23 (n=94) (n=116)	1 : 2.35 (n=55) (n=129)*
8	1 : 0.56 (n=53) (n=29)	1 : 3.43 (n=7) (n=24)	1 : 3.95 (n=21) (n=83)*	1 : 1.63 (n=19) (n=31)
9	1 : 1.21 (n=43) (n=51)	1 : 0.95 (n=21) (n=20)	1 : 1.45 (n=65) (n=94)	1 : 4.67 (n=9) (n=42)*

*includes adult salamanders whose sex was not determined

Table 3.11. Summary of gravid females and mean clutch sizes per gravid female per species (±S.E.) on preharvest compartments 7-9 (6 June-1 July 2001, 12 August-15 September 2002), postharvest compartments 7-9 (13 May-13 July 2002, 30 May-1 August 2002), and preharvest compartments 1-3 and 4-6 (13 May-13 July 2002, 30 May-1 August 2002), all night plot and coverboard sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV; % gravid females reflects percentage of all captured and processed females in a species discovered with yolked eggs.

SPECIES	% GRAVID PRE C7-9	% GRAVID POST C7-9	% GRAVID PRE C1-3	% GRAVID PRE C4-6	MEAN # EGGS PRE C7-9	MEAN # EGGS POST C7-9	MEAN # EGGS PRE C1-3	MEAN # EGGS PRE C4-6
Desmognathus ochropheus	38 (10/26)	13 (2/16)	29 (6/21)	7 (2/28)	11.8 (±0.68)	8.0 (±0.00)	8.5 (±1.50)	9.5 (±1.50)
Desmognathus m. monticola	70 (7/10)	17 (1/6)	33 (1/3)	0 (0/0)	14.9 (±1.64)	12.0 (±0.00)	12.0 (±0.00)	0.0 (±0.00)
Desmognathus f. fuscus	73 (8/11)	36 (4/11)	13 (2/15)	6 (1/18)	10.4 (±0.98)	9.3 (±2.14)	13.0 (±0.00)	13.0 (±0.00)
Plethodon cinereus	15 (2/13)	33 (2/6)	0 (0/0)	19 (5/27)	5.5 (±1.50)	4.5 (±0.50)	0.0 (±0.00)	7.2 (±0.58)

Table 3.12. Results from Pianka's index of symmetry (Krebs 1999) estimating percent similarity between the night plot and coverboard sampling techniques based on proportions of the 4 most common salamander species observed with each method (*D. f. fuscus*, *D. ochropheus*, *P. cinereus*, and *P. g. glutinosus*) for preharvest compartments 7-9 (6 June-1 July 2001, 12 August-15 September 2001), postharvest compartments 7-9 (13 May-13 July 2002, 30 May-1 August 2002), and preharvest compartments 1-3 and 4-6 (13 May-13 July 2002, 30 May-1 August 2002), MeadWestvaco industrial forest, Randolph County, WV. (Preharvest coverboard data for compartment 8 were not available.)

SPECIES	PROPORTION OF ALL INDIVIDUALS OBSERVED (NIGHT PLOTS)	PROPORTION OF ALL INDIVIDUALS OBSERVED (COVERBOARDS)	COMP	SIMILARITY NIGHT PLOTS VS. COVERBOARDS
		PREHARVEST		
Desmognathus f. fuscus	0.1728 (14/81)	0.0984 (6/61)	7	
Desmognathus ochropheus	0.1728 (14/81)	0.4918 (30/61)	7	
Plethodon cinereus	0.3210 (14/81)	0.2459 (30/61)	7	
Plethodon g. glutinosus	0.2469 (20/81)	0.0984 (6/61)	7	
				76%
Desmognathus f. fuscus	0.1124 (10/89)	0.0606 (2/33)	9	
Desmognathus ochropheus	0.4607 (41/89)	0.0576 (19/33)	9	
Plethodon cinereus	0.0562 (5/89)	0.2121 (7/33)	9	
Plethodon g. glutinosus	0.1573 (14/89)	0.0303 (1/33)	9	
				93%

SPECIES	PROPORTION OF ALL INDIVIDUALS OBSERVED (NIGHT PLOTS)	PROPORTION OF ALL INDIVIDUALS OBSERVED (COVERBOARDS)	COMP	SIMILARITY NIGHT PLOTS VS. COVERBOARDS
		POSTHARVEST		
Desmognathus f. fuscus	0.0685 (5/73)	0.2000 (5/25)	7	
Desmognathus ochropheus	0.3425 (25/73)	0.6000 (15/25)	7	
Plethodon cinereus	0.1096 (8/73)	0.1600 (4/25)	7	
Plethodon g. glutinosus	0.2192 (16/73)	0.0000 (0/25)	7	
				85%
Desmognathus f. fuscus	0.0000 (0/34)	0.3333 (3/9)	8	
Desmognathus ochropheus	0.2647 (9/34)	0.4444 (4/9)	8	
Plethodon cinereus	0.2059 (7/34)	0.1111 (1/9)	8	
Plethodon g. glutinosus	0.3235 (11/34)	0.1111 (1/9)	8	
				66%
Desmognathus f. fuscus	0.0882 (3/34)	0.0300 (3/10)	9	
Desmognathus ochropheus	0.3529 (12/34)	0.0700 (7/10)	9	
Plethodon cinereus	0.1471 (5/34)	0.0000 (0/10)	9	
Plethodon g. glutinosus	0.2941 (10/34)	0.0000 (0/10)	9	
				73%

SPECIES	PROPORTION OF ALL INDIVIDUALS OBSERVED (NIGHT PLOTS)	PROPORTION OF ALL INDIVIDUALS OBSERVED (COVERBOARDS)	COMP	SIMILARITY NIGHT PLOTS VS. COVERBOARDS
		<u>PREHARVEST</u>		
Desmognathus f. fuscus	0.1596 (15/94)	0.1563 (5/32)	1	
Desmognathus ochropheus	0.5426 (51/94)	0.6250 (20/32)	1	
Plethodon cinereus	0.0106 (1/94)	0.0938 (3/32)	1	
Plethodon g. glutinosus	0.0851 (8/94)	0.0938 (3/32)	1	
				99%
Desmognathus f. fuscus	0.0000 (0/41)	0.1429 (1/7)	2	
Desmognathus ochropheus	0.5122 (21/41)	0.2857 (2/7)	2	
Plethodon cinereus	0.1707 (7/41)	0.0000 (0/7)	2	
Plethodon g. glutinosus	0.1707 (7/41)	0.5714 (4/7)	2	
				66%
Desmognathus f. fuscus	0.0000 (0/23)	0.0000 (0/8)	3	
Desmognathus ochropheus	0.1304 (3/23)	0.0000 (0/8)	3	
Plethodon cinereus	0.0435 (1/23)	0.2500 (2/8)	3	
Plethodon g. glutinosus	0.8261 (19/23)	0.3750 (3/8)	3	
				85%

SPECIES	PROPORTION OF ALL INDIVIDUALS OBSERVED (NIGHT PLOTS)	PROPORTION OF ALL INDIVIDUALS OBSERVED (COVERBOARDS)	COMP	SIMILARITY NIGHT PLOTS VS. COVERBOARDS
		<u>PREHARVEST</u>		
Desmognathus f. fuscus	0.0417 (2/48)	0.0526 (1/19)	4	
Desmognathus ochropheus	0.2292 (11/48)	0.3158 (6/19)	4	
Plethodon cinereus	0.1042 (5/48)	0.2632 (5/19)	4	
Plethodon g. glutinosus	0.4583 (22/48)	0.3684 (7/19)	4	
				93%
Desmognathus f. fuscus	0.0364 (2/55)	0.1290 (4/31)	5	
Desmognathus ochropheus	0.2364 (13/55)	0.2258 (7/31)	5	
Plethodon cinereus	0.2000 (11/55)	0.4839 (15/31)	5	
Plethodon g. glutinosus	0.4000 (22/55)	0.0968 (3/31)	5	
				68%
Desmognathus f. fuscus	0.0323 (2/62)	0.1698 (9/53)	6	
Desmognathus ochropheus	0.3548 (22/62)	0.4340 (23/53)	6	
Plethodon cinereus	0.2581 (16/62	0.3774 (20/53)	6	
Plethodon g. glutinosus	0.2581 (16/62)	0.0189 (1/53)	6	
				86%

CHAPTER 3

FIGURES

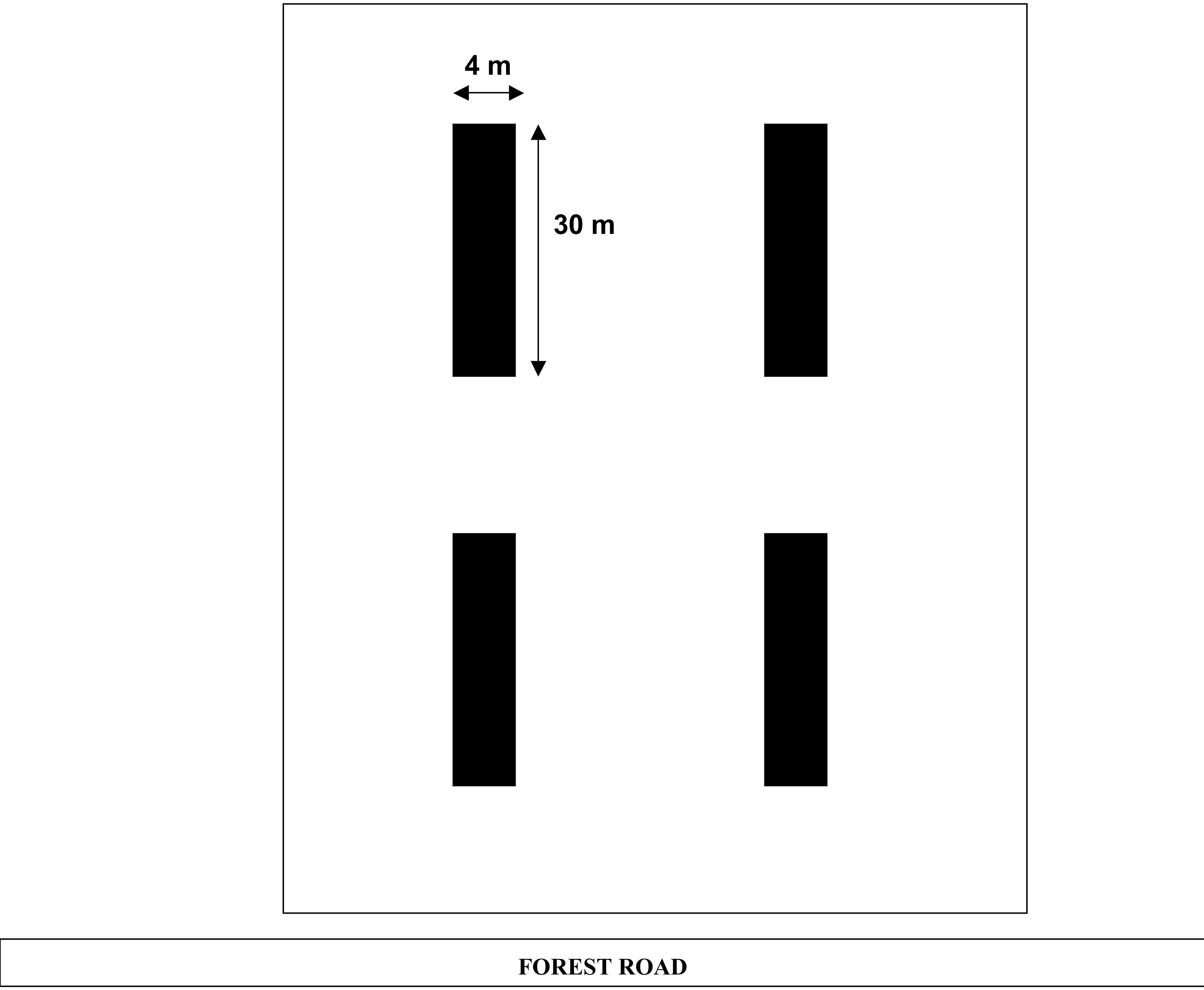

Figure 3.1. Schematic of theoretical reference cut (not to scale) showing 30 m x 4 m sampling plots (n=4), used for nighttime area-constrained searches in 2001 and 2002, MeadWestvaco industrial forest, Randolph County, WV.

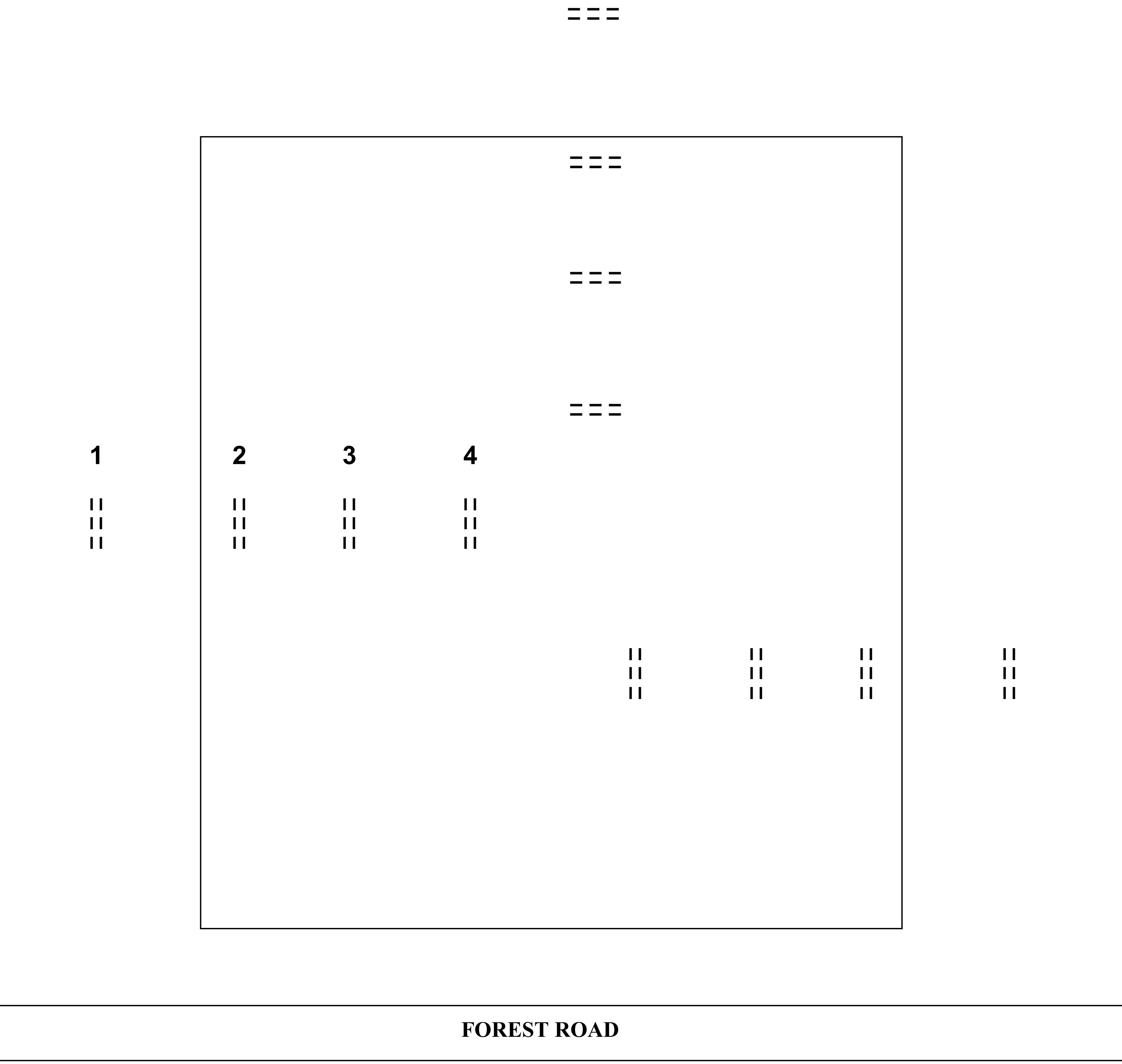

Figure 3.2. Schematic of theoretical reference cut (not to scale) showing 3 coverboard transects on the 3 sides not adjacent to a road, with 4 stations per transect and 6 boards per station used for daytime searches in 2001 and 2002; station 1=40-50 m outside clearcut in mature forest, station 2=5-10 m inside clearcut, station 3=40-50 m inside clearcut, and station 4=≥100 m inside clearcut, MeadWestvaco industrial forest, Randolph County, WV.

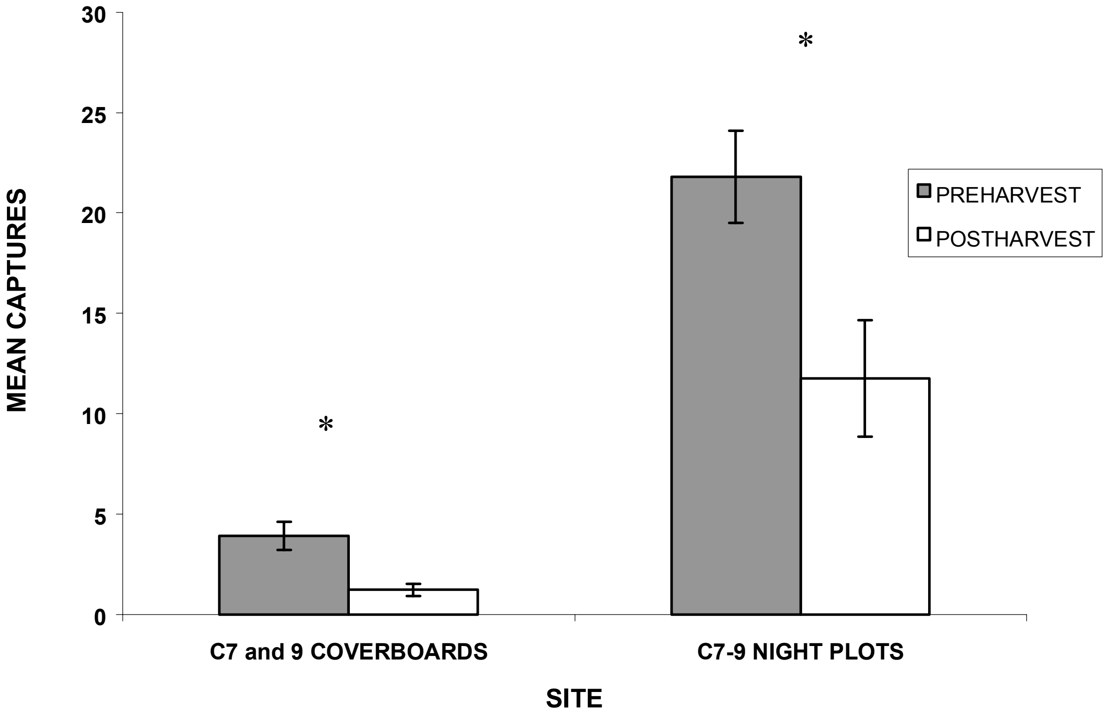

Figure 3.3. Histogram displaying mean captures (±S.E.) per compartment for compartments 7 and 9 (preharvest coverboard data for compartment 8 were not available) from 3 preharvest and postharvest surveys (12 August-15 September 2001, 30 May-1 August 2002) and mean captures (±S.E.) per compartment for compartments 7-9 from 4 preharvest and postharvest night plot surveys (6 June-1 July 2001, 13 May-13 July 2002), MeadWestvaco industrial forest, Randolph County, WV. An asterisk (*) above error bars indicates a significant difference at the 0.10 level (from ANOVA) between preharvest and postharvest relative abundance.

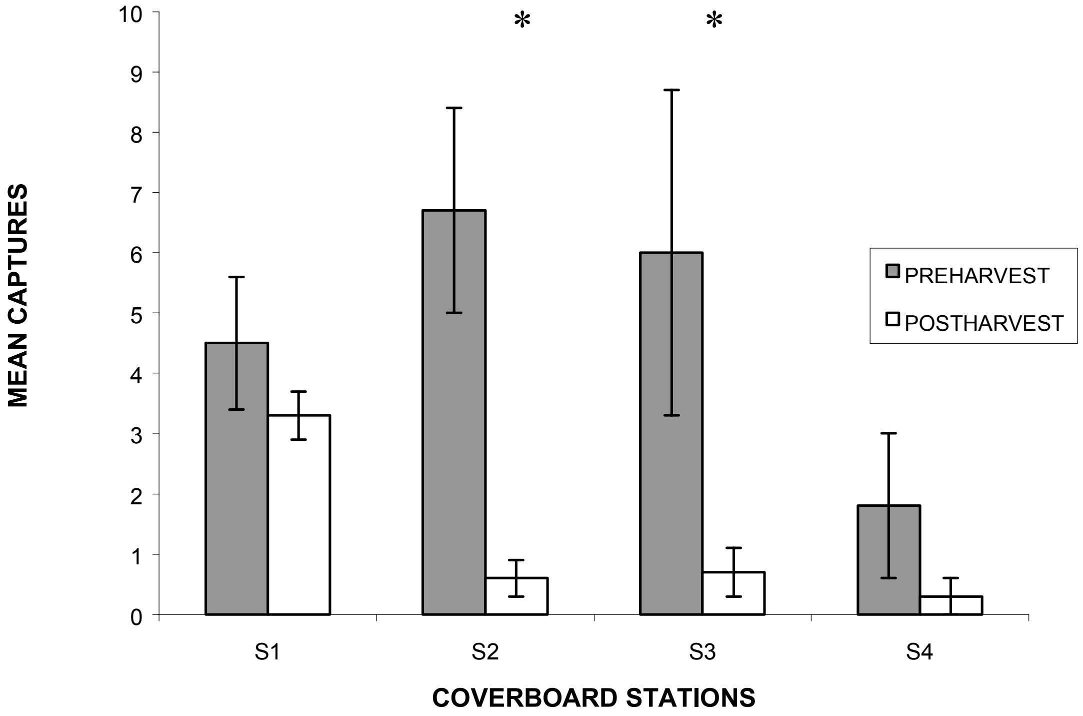

Figure 3.4. Histogram showing differences in preharvest and postharvest mean captures per coverboard station (±S.E.) on compartments 7 and 9 combined, all sampling efforts pooled, (12 August-15 September 2001, 30 May-1 August 2002), MeadWestvaco industrial forest, Randolph County, WV. An asterisk (*) indicates a significant difference at the 0.10 level (from ANOVA) between preharvest and postharvest relative abundance (station 1=40-50 m outside clearcut in mature forest, station 2=5-10 m inside clearcut, station 3=40-50 m inside clearcut, and station 4=≥100 m inside clearcut).

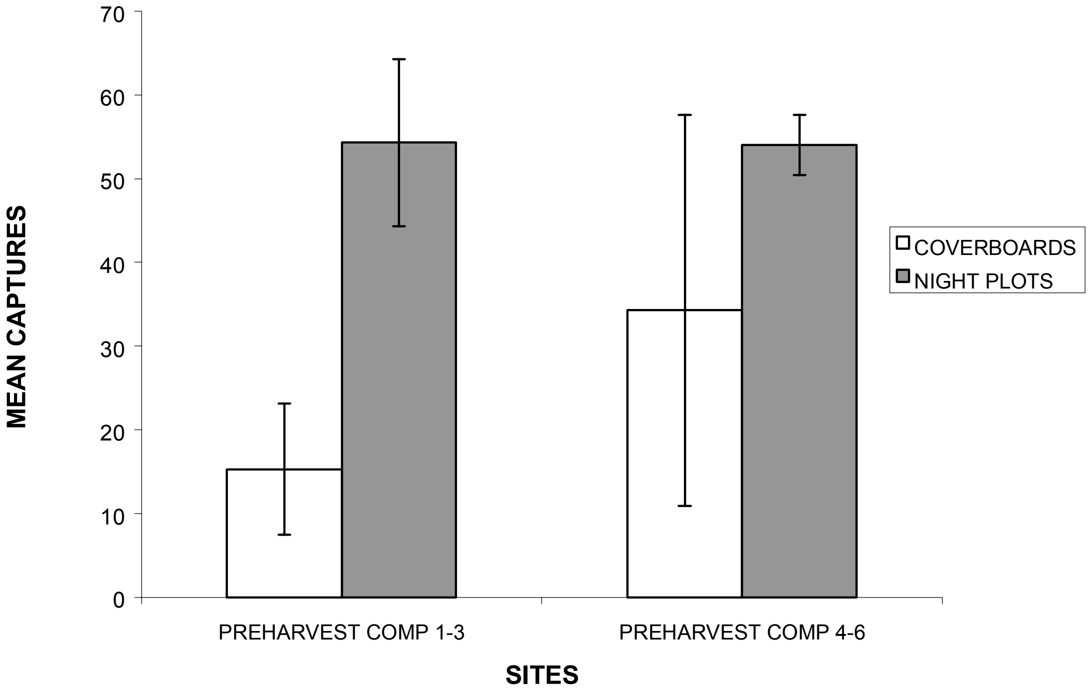

Figure 3.5. Histogram displaying mean captures (±S.E.) per compartment for compartments 1-3 and 4-6 from 3 preharvest coverboard surveys (30 May-1 August 2002) and 4 preharvest night plot surveys (13 May-13 July 2002), MeadWestvaco industrial forest, Randolph County, WV.

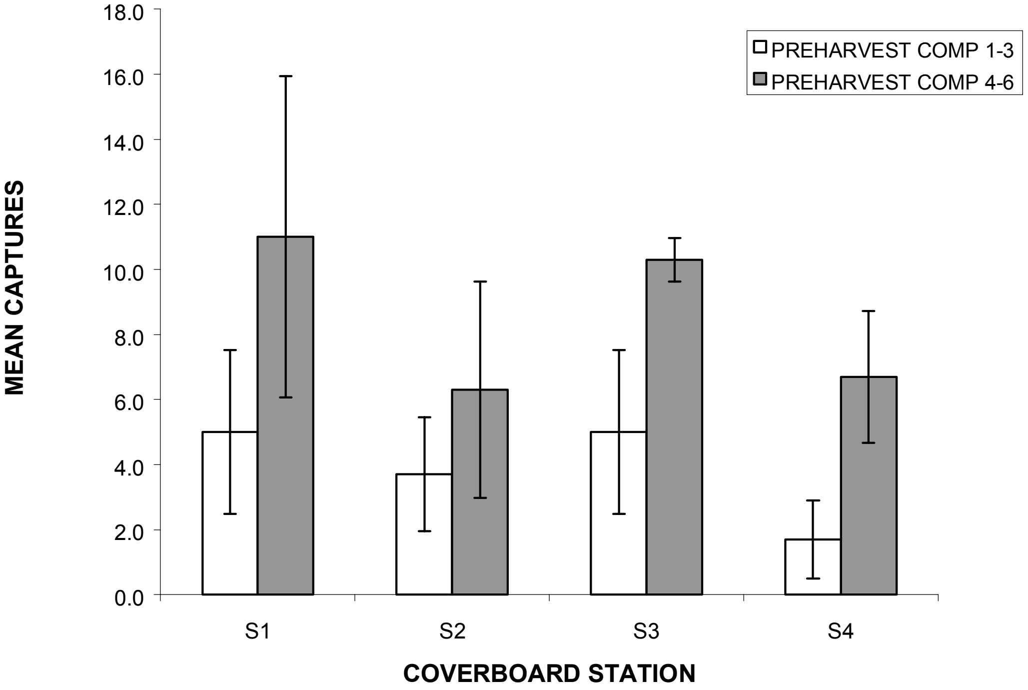

Figure 3.6. Histogram showing differences in preharvest mean captures per coverboard station (±S.E.) on compartments 1-3 and 4-6 combined, all sampling efforts pooled, (30 May-1 August 2002), MeadWestvaco industrial forest, Randolph County, WV. (Station 1=40-50 m outside clearcut in mature forest, station 2=5-10 m inside clearcut, station 3=40-50 m inside clearcut, and station 4=≥100 m inside clearcut.)

CHAPTER 4: CONCLUSIONS

SUMMARY

In this thesis I examined industrial forest habitat across the landscape in terms of which habitat characteristics were important to predict amphibian relative abundance and which features of natural cover objects were important to predict salamanders' use in relation to what was available on the forest floor. I also examined first year responses of amphibian populations and communities to clearcutting and compared the 2 sampling techniques of night plot searches vs. coverboard surveys.

In Chapter 2, I assessed habitat characteristics across an industrial forest landscape and examined which habitat variables were significant in predicting amphibian relative abundance. From natural cover object use/availability data, I analyzed salamander preferences for sizes, shapes, and types of rock cover objects, and sizes and levels of decomposition of wood cover objects. Not including the year effect that was significant, the most important habitat variables in our 10 m x 10 m plots for predicting amphibian relative abundance were the amount of rock cover within plots and plots that were located in SMZs, $\leq$15 m from perennial or ephemeral streams or perennial ponds. Other habitat features that were significant in models were % canopy cover, % woody stem cover ($\leq$7.5 cm DBH), % herbaceous vegetation, soil pH, site index, and a count of available woody debris of decomposition classes 3-5 along diagonal transects. Overall, salamanders preferred rock cover objects to wood relative to the amount available of each. When salamanders used wood, they preferred debris in a higher state of decomposition (classes 3-5), of width class 5-10 cm, and of length class $\leq$50 cm. When salamanders used rocks, they preferred rocks of length class 31-40 cm, flat rocks over angular shapes and preferred flagstones over all other types of rocks.

In Chapter 3, I provided preharvest and first year postharvest baseline data across clearcut reference areas on 9 forest compartments. Between preharvest and postharvest compartments, I examined differences in community characteristics and distribution within clearcuts in relation to surrounding mature forest, population relative abundance, demographics, morphology, and fertility and fecundity. Finally, I used a similarity index to compare night plot and coverboard sampling techniques in terms of proportions of 4 common salamanders species captured on compartments using each method.

Species richness decreased from preharvest to postharvest for both night plot and coverboard sampling, but species diversity showed little change. Relative abundance from coverboard data decreased significantly preharvest to postharvest; relative abundance from night plot data decreased but not significantly preharvest to postharvest. Distribution within reference cuts, as measured by relative abundance at coverboard station distances away from adjacent mature forest, did not change significantly at station 1 placed in mature forest (40-50 m away from clearcut) or at station 4 ($\geq$100 m inside clearcut), but stations 2 (5-10 m inside clearcut) and 3 (40-50 m inside clearcut) did show significant decreases in relative abundance for all compartments combined.

Overall, most population demographics and morphological characteristics did not change significantly preharvest to postharvest; however, juveniles of 2 salamander species actually showed significant increases in mean M/SVL ratio (g/mm), an index of physical condition, preharvest to postharvest. Adult sex ratio remained constant preharvest to postharvest for all compartments combined. In age class distribution, adults increased in relation to juveniles from preharvest to postharvest, but this difference was not statistically significant.

Pianka's index displayed high levels of symmetry on average (>80%) between the 2 sampling techniques of night plots vs. coverboards used on clearcut reference areas in terms of proportions of the 4 most common salamander species captured.

FOREST MANAGEMENT RECOMMENDATIONS

Although my research did not address many of the techniques used to protect water quality, knowledge of amphibian natural history suggests that amphibian populations will benefit from BMPs. Above all, forest managers should be encouraged to continue employing BMPs--minimizing soil compaction and erosion, creating water bars on steep-sloping skid trails, leaving a duff and slash layer on the forest floor after timber harvesting, leaving an intact forest buffer in SMZs, etc. BMPs not only protect water quality and soil integrity to ensure forest regeneration, but these practices may also help lessen the negative impacts of timber harvesting on amphibians.

As evident in our count of available aquatic habitats across the landscape, a substantial proportion of those habitats (16%) were associated with skid trail ephemeral pools and seeps at water bars. These areas provide crucial aquatic resources for all amphibians but especially those that rely on pools for breeding (e.g., *Ambystoma* spp. and *Rana* spp.), as long as these areas retain water long enough for metamorphs to emerge. Creating water bars and low-lying areas or depressions in skid trails as a result of timber harvest activities could increase the potential amount of aquatic habitat available for amphibians throughout the forest. However, if these pools dry too quickly, they may serve as traps causing reproductive failure in pool breeding amphibians.

Also, it is common knowledge in the literature, and I have shown in this project as well, that salamanders rely on highly decomposed woody debris as cover objects, under which they forage for food, lay eggs, and seek refuge from hot, dry conditions. BMPs that require a large percentage of the duff and slash layer left after harvest to remain on site, benefit salamanders after timber harvest by providing them with immediate cover and some protection from the negative effects of canopy removal. In the future, forest managers could consider protecting a greater proportion of snags and dead trees, if feasible and logistically possible, from being clearcut. Not only do snags provide valuable habitat and foraging opportunities for a number of cavity-nesting birds and small mammals, but the potential input of higher decomposed woody debris (or at least wood that should progress to a higher state of decomposition more quickly than newly fallen, live trees) to the forest floor in the near future after a harvest would benefit salamander populations trying to recover and recolonize.

One of the most important BMPs for amphibians is the establishment of intact forest buffers at SMZs. As I have shown in chapter 2 with the regression models, the proximity to perennial and ephemeral streams and perennial ponds is a major factor influencing abundance, responsible for over 23% of the inherent variation in relative abundance. I am unaware of how frequently forest managers choose to establish SMZs at intermittent streams or under what criteria they make those decisions. However, if managers could leave more ephemeral streams along with perennial streams buffered with intact forest, amphibian populations, as well as other fauna, would benefit. Buffers around ephemeral pools and wetlands may also protect habitat for species that rely on those areas for breeding, even though it is unknown whether these species migrate across large clearcuts to find these areas. Researchers have shown that amphibians readily choose forested corridors rather than open fields for dispersal and that survival is lower and the rate of dessication and/or predation is higher in open field habitat, suggesting forest fragmentation has negative effects on amphibian populations (Rothermel and Semlitsch 2002).

The size of SMZ buffers is another area where forest managers could choose to have significant positive impacts on amphibian populations. Buffer size could be dependent on the quality of habitat for amphibians and other wildlife, with more intact forest left at streams and ponds/pools in high quality habitat (e.g., high site index, northern or eastern exposure, abundant rock and wood cover objects, undisturbed leaf litter layer, etc.). Semlitsch (2002) suggested managers leave buffers of no less than 164 m around wetlands to allow dispersing amphibians access to diverse microhabitats such as springs, caves, leaf litter, and coarse woody debris. Similarly, other researchers have suggested that creating biologically meaningful buffers around riparian areas and wetlands that protect core habitats required for nesting, overwintering, and foraging is a critical element of amphibian conservation (Semlitsch and Bodie 2003).

A possible management strategy would be to preserve corridors of intact, mature forest between SMZs and high quality upland habitat, between SMZs and other aquatic habitats (e.g., ephemeral pools or wetlands), and between high quality upland habitats. This habitat connectivity among aquatic habitats and corridors of mature forest would not only help ensure continuance of amphibian metapopulations and aid the movement of populations away from forest disturbance but also create pathways for individuals to recolonize habitats after timber harvesting (Bury 1988, Foley 1994, Semlitsch 2002, Rothermel and Semlitsch 2003). Baughman (2000) in his dissertation supports the use of corridors as a conservation tool for amphibians (as well as reptiles) in managed forests. His study suggests that, in the short-term, corridors of 100 m in width facilitate herpetofaunal movement and maintain community assemblages similar to the forest stands from which the corridors originated. However, long-term monitoring is still needed to understand effects of habitat corridors on amphibian conservation (Baughman 2000).

For another future management strategy, the current practice of adding lime to major first order streams on the WERF should continue. I discovered in the regression modeling on SMZ plots that higher soil pH levels were associated with greater amphibian relative abundance. Our SMZ plots that were immediately downstream of liming stations did indeed have higher soil pHs compared to SMZ plots that were not located downstream of a liming station. As discussed in Chapter 2, salamanders are at risk of toxicity at lower levels of soil pH (<3.5) and thrive in habitats with a pH of 5-6. Managers might consider the feasibility of adding lime to upland habitats that have extremely low pH levels from acid rain deposition or other factors.

Finally, in my project I have established that relationships between amphibian abundance and higher quality habitat (e.g., near aquatic habitats, abundant rock and wood cover objects, thick canopy cover, higher soil pH, high site index, etc.) exist on MeadWestvaco forest and are well-documented in the literature. I have provided models predicting abundance based on habitat characteristics for future researchers to verify or refute and for managers to use in forest management decisions.

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APPENDICES

Appendix A. Dates of all 2001-2002 amphibian sampling and compartment reference cut harvest schedule, MeadWestvaco industrial forest, Randolph County, WV.

TERRESTRIAL SAMPLING DATES

2001	2002
21 May	27 May
22 May	28 May
23 May	12 June
29 May	15 June
30 May	24 June
4 June	25 June
5 June	8 July
6 June	9 July
12 June	12 July
13 June	16 July
15 June	17 July
20 June	18 July
21 June	22 July
22 June	24 July
27 June	25 July
28 June	27 July
5 July	30 July
6 July	31 July
7 July	
9 July	
11 July	
12 July	
13 July	
16 July	
17 July	
20 July	
26 July	
27 July	
28 July	
30 July	
31 July	

COVERBOARD SAMPLING DATES

2001	2002
12 August	30 May
7 September	3 June
15 September	5 June
	19 June
	20 June
	1 July
	2 July
	29 July
	1 August

NIGHT PLOT SAMPLING DATES

2001	2002
6 June	13 May
13 June	17 May
1 July	28 May
17 July*	6 June
18 July*	13 June
	27 June
	9 July
	10 July
	13 July

* indicates extra sampling (repeats) of plots on compartment 7 and 9 after timber harvesting on compartment 8 had started; these extra data were not included in analyses.

2001-2003 COMPARTMENT REFERENCE CUT HARVEST SCHEDULE

REPLICATE BLOCK	COMPARTMENT	HARVEST TREATMENT	HARVEST DATE
A	1	Intensive (20-yr)	Fall 2003
	2	Moderate (40-yr)	Fall 2003
	3	Light (80-yr)	Fall 2003
B	4	Light (80-yr)	Fall 2002
	5	Intensive (20-yr)	Fall 2002
	6	Moderate (40-yr)	Fall 2002
C	7	Moderate (40-yr)	Fall 2001
	8	Intensive (20-yr)	Summer 2001
	9	Light (80-yr)	Fall 2001

Appendix B. Summary tables of all captured and processed salamanders by species and sex with missing or regenerating tails on all 2001 (n=151) and 2002 (n=219) 10 m x 10 m terrestrial plots and on preharvest and postharvest night plots and coverboards on preharvest compartments 7-9 (6 June-1 July 2001, 12 August-15 September 2001), postharvest compartments 7-9 (13 May-13 July 2002, 30 May-1 August 2002), and preharvest compartments 1-3 and 4-6 (13 May-13 July 2002, 30 May-1 August 2002), all night plot and coverboard sampling efforts pooled, MeadWestvaco industrial forest, Randolph County, WV.

2001-2002 TERRESTRIAL SAMPLING

SPECIES	SEX	% OF ALL IN SPECIES (2001)	% OF ALL IN SPECIES (2002)
Desmognathus ochropheus	M	15 (9/61)	3 (2/78)
	F	16 (9/55)	4 (2/46)
	J	9 (8/94)	2 (1/55)
Desmognathus m. monticola	M	8 (4/53)	N/A
	F	3 (1/30)	4 (1/24)
	J	5 (1/21)	5 (1/19)
Desmognathus f. fuscus	M	12 (5/43)	N/A
	F	10 (5/51)	N/A
	J	2 (1/65)	N/A
Eurycea b. bislineata	A	4 (1/ 23)	N/A
	J	N/A	N/A
Plethodon cinereus	M	11 (5/44)	6 (1/16)
	F	17 (7/ 41)	3 (1/36)
	J	16 (16/98)	6 (2/33)
Plethodon g. glutinosus	A	62 (8/ 13)	N/A
	M	N/A	50 (1/2)
	F	N/A	N/A

PREHARVEST AND POSTHARVEST—NIGHT PLOTS AND COVERBOARDS

SPECIES	SEX	% OF ALL IN SPECIES (PRE C7-9)	% OF ALL IN SPECIES (POST C7-9)	% OF ALL IN SPECIES (PRE C1-3)	% OF ALL IN SPECIES (PRE C 4-6)
Desmognathus ochropheus	F	19 (5/11)	N/A	N/A	4 (1/28)
	M	10 (3/30)	16 (4/25)	N/A	18 (4/22)
	J	23 (12/54)	57 (13/23)	8 (3/40)	N/A
Desmognathus m. monticola	F	10 (1/1)	N/A	N/A	N/A
	M	8 (1/12)	N/A	N/A	N/A
Desmognathus spp.	J	N/A	100 (1/1)	50 (1/2)	N/A
Desmognathus f. fuscus	F	N/A	N/A	9 (1/11)	N/A
	M	29 (2/7)	N/A	N/A	17 (1/6)
Eurycea b. bislineata	A	50 (1/2)	N/A	N/A	N/A
	J	67 (2/3)	N/A	N/A	N/A
Plethodon cinereus	F	38 (5/39)	N/A	N/A	26 (7/27)
	M	37 (7/19)	N/A	N/A	30 (3/10)
	J	13 (5/39)	13 (2/15)	33 (3/9)	3 (1/33)
Plethodon g. glutinosus	A	43 (10/23)	N/A	N/A	N/A
	F	N/A	33 (2/6)	N/A	18 (2/11)
	M	N/A	50 (1/2)	40 (2/5)	25 (2/8)
	J	19 (9/48)	26 (5/19)	8 (2/24)	5 (2/42)
Plethodon wehrlei	J	N/A	N/A	N/A	10 (1/10)

Appendix C. List of Universal Transverse Mercators (UTMs) recorded at 2002 coverboard transects and stations on compartments 1-9 (reference cuts) and at aquatic habitats encountered on terrestrial transects (including those sampled as SMZ plots), using a Garmin 12 X^{TM} handheld Global Positioning System (GPS) and NAD 83 datum, MeadWestvaco industrial forest, Randolph County, WV.

DATE	COMPARTMENT	TRANSECT	STATION	UTM EASTING	UTM NORTHING
6/17/2002	1	1	1	0581021	4298002
6/17/2002	1	1	2	0581002	4298004
6/17/2002	1	1	3	0581002	4298091
6/17/2002	1	1	4	0581022	4298125
6/17/2002	1	2	1	0581123	4298343
6/17/2002	1	2	2	0581102	4298355
6/17/2002	1	2	3	0581062	4298392
6/17/2002	1	2	4	0581028	4298419
6/17/2002	1	3	1	0581290	4298945
6/17/2002	1	3	2	0581278	4298908
6/17/2002	1	3	3	0581289	4298862
6/17/2002	1	3	4	0581297	4298841
6/23/2002	2	1	1	0585740	4295754
6/23/2002	2	1	2	0585725	4295813
6/23/2002	2	1	3	0585711	4295862
6/23/2002	2	1	4	0585691	4295908
6/23/2002	2	2	1	0585713	4296062
6/23/2002	2	2	2	0585725	4296012
6/23/2002	2	2	3	0585739	4295970
6/23/2002	2	2	4	0585743	4295878
6/23/2002	2	3	1	0585932	4295891
6/23/2002	2	3	2	0585875	4295946
6/23/2002	2	3	3	0585852	4295960
6/23/2002	2	3	4	0585825	4295970
6/20/2002	3	1	1	0580891	4295108
6/20/2002	3	1	2	0580925	4295155
6/20/2002	3	1	3	0580929	4295198
6/20/2002	3	1	4	0580950	4295264
6/20/2002	3	2	1	0580965	4295807
6/20/2002	3	2	2	0581018	4295749
6/20/2002	3	2	3	0581033	4295702
6/20/2002	3	2	4	0581040	4295665
6/20/2002	3	3	1	0581148	4295976
6/20/2002	3	3	2	0581153	4295937
6/20/2002	3	3	3	0581162	4295911
6/20/2002	3	3	4	0581174	4295863

7/20/2002	4	1	1	0582029	4287297
7/20/2002	4	1	2	0582041	4287346
7/20/2002	4	1	3	0582058	4287385
7/20/2002	4	1	4	0582095	4287399
7/20/2002	4	2	1	0582449	4287760
7/20/2002	4	2	2	0582429	4287700
7/20/2002	4	2	3	0582427	4287690
7/20/2002	4	2	4	0582405	4287627
7/20/2002	4	3	1	0582552	4287543
7/20/2002	4	3	2	0582518	4287568
7/20/2002	4	3	3	0582505	4287565
7/20/2002	4	3	4	0582419	4287570
7/20/2002	5	1	1	0578758	4284532
7/20/2002	5	1	2	0578750	4284454
7/20/2002	5	1	3	0578759	4284340
7/20/2002	5	1	4	0578745	4284244
7/20/2002	5	2	1	0578632	4284192
7/20/2002	5	2	2	0578622	4284228
7/20/2002	5	2	3	0578603	4284278
7/20/2002	5	2	4	0578615	4284291
7/20/2002	5	3	1	0578615	4284015
7/20/2002	5	3	2	0578565	4284020
7/20/2002	5	3	3	0578528	4284042
7/20/2002	5	3	4	0578479	4284066
7/20/2002	6	1	1	0582146	4286424
7/20/2002	6	1	2	0582153	4286325
7/20/2002	6	1	3	0582152	428269
7/20/2002	6	1	4	0582126	4286224
7/20/2002	6	2	1	0581553	4286074
7/20/2002	6	2	2	0581607	4286063
7/20/2002	6	2	3	0581636	4286088
7/20/2002	6	2	4	0581682	4286110
7/20/2002	6	3	1	0581693	4285672
7/20/2002	6	3	2	0581695	4285713
7/20/2002	6	3	3	0581698	4285777
7/20/2002	6	3	4	0581711	4285828

6/17/2002	7	1	1	0578279	4282934
6/17/2002	7	1	2	0578291	4282993
6/17/2002	7	1	3	0578294	4283039
6/17/2002	7	1	4	0578311	4283088
6/17/2002	7	2	1	0578036	4283137
6/17/2002	7	2	2	0578106	4283131
6/17/2002	7	2	3	0578132	4283172
6/17/2002	7	2	4	0578158	4283194
6/17/2002	7	3	1	0578472	4283276
6/17/2002	7	3	2	0578510	4283191
6/17/2002	7	3	3	0578529	4283156
6/17/2002	7	3	4	0578537	4283155
6/20/2002	8	3	1	0581610	4284045
6/20/2002	8	3	2	0581579	4283994
6/20/2002	8	3	3	0581569	4283950
6/20/2002	8	3	4	0581548	4283908
6/20/2002	8	2	1	0581239	4284077
6/20/2002	8	2	2	0581322	4283914
6/20/2002	8	2	3	0581349	4283899
6/20/2002	8	2	4	0581381	4283849
6/20/2002	8	1	1	0581364	4283614
6/20/2002	8	1	2	0581372	4283655
6/20/2002	8	1	3	0581364	4283725
6/20/2002	8	1	4	0581371	4283769
6/21/2002	9	1	1	0580919	4282205
6/21/2002	9	1	2	0580930	4282148
6/21/2002	9	1	3	0580945	4282107
6/21/2002	9	1	4	0580948	4282046
6/20/2002	9	2	1	0581132	4282047
6/20/2002	9	2	2	0581096	4282099
6/20/2002	9	2	3	0581058	4282111
6/20/2002	9	2	4	0581019	4282144
6/21/2002	9	3	1	0580947	4281704
6/21/2002	9	3	2	0580913	4281775
6/21/2002	9	3	3	0580898	4281818
6/21/2002	9	3	4	0580891	4281868

Note: Sampling on compartment 2 was not completed in the reference cut area that will be used in future surveys due to an error that occurred when forest stands were marked for harvest. The location of reference cut 2 that will be used in subsequent years is E: 0586650, N: 4297150.

DATE	2002 SMZ PLOT SAMPLED	UTM EASTING	UTM NORTHING	AQUATIC HABITAT TYPE	COMMENTS
05/27/02	C5T1R1	0580231	4286122	INTERMITTENT STREAM	
05/28/02	C4T1P2	0581354	4288081	INTERMITTENT STREAM	
06/12/02	C7T1P2	0578464	4283610	INTERMITTENT STREAM	
06/12/02	C9T1R1	0581974	4282973	PERENNIAL STREAM	
06/15/02	C6T1P4	0582564	4283598	INTERMITTENT STREAM	
06/24/02	C1T1R1	0582061	4298446	INTERMITTENT STREAM	
06/24/02	C1T1R3	0581522	4298407	PERENNIAL STREAM	LOST RUN
06/25/02	C5T2P2	0578552	4284171	INTERMITTENT STREAM	
06/25/02	C5T2R3	0578502	4284146	INTERMITTENT STREAM	
06/25/02	C6T2R1	0582025	4285874	PERENNIAL STREAM	MITCHELL LICK
07/08/02	C7T2P2	0578917	4282498	INTERMITTENT STREAM	
07/08/02	C7T2P4	0578826	4282495	INTERMITTENT STREAM	
07/08/02	C8T2P3	0579807	4282543	PERENNIAL STREAM	
07/08/02	C8T2R1	0579456	4282530	INTERMITTENT STREAM	
07/08/02	C9T2R3	0581185	4282107	PERENNIAL STREAM	KITTLE CREEK
07/09/02	C2T2P4	0584799	4298207	INTERMITTENT STREAM	
07/09/02	C3T2P1	0581467	4296784	INTERMITTENT STREAM	
07/12/02	C4T3R1	0581668	4286924	INTERMITTENT STREAM	
07/12/02	C5T3P2	0579718	4284795	PERENNIAL STREAM	BIRCH FORK
07/12/02	C5T3P6	0579215	4285079	INTERMITTENT STREAM W/POOL	
07/12/02	C6T3R1	NO READING	NO READING	PERENNIAL STREAM	KITTLE CREEK
07/16/02	C7T3R1	0578513	4281619	PERENNIAL STREAM	BIRCH FORK

07/16/02	C8T3P3	0579799	4281623	PERENNIAL STREAM	
07/16/02	C8T3P6	0580199	4281528	PERENNIAL STREAM	
07/16/02	C9T3P1	0580957	4281177	PERENNIAL STREAM	KITTLE CREEK
07/17/02	C1T3R2	0580751	4298970	INTERMITTENT STREAM	
07/17/02	C2T3P2	0583859	4297215	INTERMITTENT STREAM	
07/17/02	C3T3P1	0582375	4296011	INTERMITTENT STREAM	
07/18/02	C3T3P5	0581178	4295664	INTERMITTENT STREAM	
07/22/02	C4T4P6	0581040	4287834	PERENNIAL STREAM	ROCKY RUN
07/22/02	C5T4R1	0579897	4285357	INTERMITTENT STREAM	
07/22/02	C5T4R3	0580485	4285165	PERENNIAL STREAM	ROCKY RUN
07/22/02	C6T4P2	0582651	4284131	INTERMITTENT STREAM	
07/22/02	C6T4P4	0582377	4284069	PERENNIAL STREAM	
07/24/02	C7T4P1	0578655	4283028	PERENNIAL STREAM	
07/24/02	C7T4P5	0578264	4282985	INTERMITTENT STREAM	
07/24/02	C7T4P6	0578252	4283003	INTERMITTENT STREAM	
07/24/02	C8T4P1	0580236	4283311	PERENNIAL STREAM	ROCKY RUN
07/24/02	C8T4R2	0580262	4283282	PERENNIAL STREAM	ROCKY RUN
07/24/02	C8T4R4	0579883	4283237	INTERMITTENT STREAM	
07/24/02	C9T4P3	0582305	4282166	INTERMITTENT STREAM	
07/24/02	C9T4P5	0581542	4282426	INTERMITTENT STREAM	
07/24/02	C9T4P6	0581491	4282452	PERENNIAL STREAM	
07/25/02	C1T4P1	0581666	4298668	PERENNIAL STREAM	LOST RUN
07/25/02	C1T4P3	0582162	4298752	PERENNIAL STREAM	MIDDLE FORK
07/25/02	C1T4P4	0582409	4298749	PERENNIAL STREAM	MIDDLE FORK
07/25/02	C1T4R1	0581669	4298663	PERENNIAL STREAM	LOST RUN

07/25/02	C2T4P1	0584616	4297176	INTERMITTENT STREAM	
07/25/02	C3T4P1	0580821	4296523	INTERMITTENT STREAM	
07/25/02	C3T4P3	0581289	4296528	PERENNIAL STREAM	
07/25/02	C3T4P5	0580575	4296466	INTERMITTENT STREAM	
07/27/02	C4T5R1	0582318	4286572	PERENNIAL STREAM	MITCHELL LICK
07/27/02	C5T5P2	0578410	4284709	PERENNIAL STREAM	
07/27/02	C5T5P4	0579305	4284049	PERENNIAL STREAM	BIRCH FORK
07/27/02	C6T5P2	0581670	4284694	INTERMITTENT STREAM	MITCHELL LICK TRIBUTARY
07/30/02	C1T5R2	0581310	4298006	PERENNIAL STREAM	LOST RUN
07/30/02	C1T5R3	0580562	4297918	INTERMITTENT STREAM	
07/30/02	C2T5P1	0585744	4297491	INTERMITTENT STREAM	
07/30/02	C2T5P4	0585555	4297260	INTERMITTENT STREAM	
07/30/02	C2T5P6	0585404	4296857	POND	
07/30/02	C3T5P3	0581356	4296375	INTERMITTENT STREAM	
07/30/02	C3T5P4	0581137	4296347	INTERMITTENT STREAM	
07/30/02	C3T5P5	0580995	4296314	INTERMITTENT STREAM	THREE FORKS TRIBUTARY
07/31/02	C7T5P1	0578574	4282110	PERENNIAL STREAM	BIRCH FORK
07/31/02	C8T5P2	0579886	4282127	PERENNIAL STREAM	ROCKY RUN
07/31/02	C9T5R1	0580970	4281815	PERENNIAL STREAM	KITTLE CREEK

DATE	COMPARTMENT	TRANSECT	UTM EASTING	UTM NORTHING	COMMENTS
05/27/02	5	1	0580535	4285936	SEEP
05/27/02	5	1	0580062	4286260	SEEP
05/27/02	5	1	0580046	4286238	SEEP
05/27/02	5	1	0580226	4286131	SPRING
05/27/02	5	1	0578565	4284264	SPRING/SEEP
05/28/02	4	1	0581142	4288072	SKID TRAIL SEEP
05/28/02	4	1	0581599	4288099	SKID TRAIL SEEP
06/12/02	7	1	0578248	4283579	INTERMITTENT STREAM
06/12/02	7	1	0578583	4283586	INTERMITTENT STREAM
06/12/02	7	1	0577762	4283502	INTERMITTENT STREAM
06/12/02	8	1	0581406	4283783	SKID TRAIL SEEP
06/12/02	8	1	0581313	4283760	SKID TRAIL SEEP
06/12/02	9	1	0580800	4282957	SEEP
06/12/02	9	1	0581830	4282993	PERRENIAL STREAM
06/12/02	9	1	0580785	4282945	INTERMITTENT STREAM
06/12/02	9	1	0580716	4282922	INTERMITTENT STREAM
06/15/02	6	1	0582129	4283589	SKID TRAIL RIVULET
06/15/02	6	1	0582429	4283585	
06/24/02	2	1	0583547	4298608	SEEP
06/24/02	3	1	0581567	4296163	SKID TRAIL RIVULET

06/24/02	3	1	0581385	4296068	SKID SEEP
06/24/02	3	1	0581774	4296206	INTERMITTENT STREAM
06/24/02	3	1	0581564	4296134	
06/24/02	1	1	0581552	4298418	INTERMITTENT STREAM
06/24/02	1	1	0581469	4298384	INTERMITTENT STREAM
06/25/02	6	2	0582149	4285824	SKID SEEP
06/25/02	4	2	0583218	4286988	INTERMITTENT STREAM
07/08/02	8	2	0579265	4282548	SEEP
07/08/02	7	2	0579117	4282504	
07/08/02	8	2	0579265	4282548	SEEP
07/08/02	9	2	0581451	4282039	
07/08/02	9	2	0581215	4282097	SKID TRAIL SEEP
07/09/02	3	2	0581539	4296842	INTERMITTENT STREAM
07/12/02	4	3	0581047	4287001	CULVERT DRAIN
07/12/02	5	3	0579852	4284748	SEEP
07/12/02	5	3	0579258	4285028	INTERMITTENT STREAM
07/12/02	6	3	0581030	4285056	SEEP
07/12/02	6	3	0580971	4285052	SEEP
07/16/02	7	3	0578721	4281694	SPRING
07/16/02	7	3	0578635	4281664	SEEP
07/16/02	7	3	0578635	4281665	SEEP/SPRING

07/16/02	7	3	0578721	4281694	SPRING
07/16/02	9	3	0581059	4281176	SKID TRAIL SEEP
07/16/02	9	3	0581048	4281175	SKID TRAIL RIVULET
07/17/02	2	3	0583705	4296844	SEEP
07/17/02	1	3	0580785	4299005	INTERMITTENT STREAM
07/17/02	1	3	0580716	4298958	STREAM
07/17/02	2	3	0583705	4296844	SEEP
07/18/02	3	3	0581149	4295678	SKID TRAIL SEEP
07/22/02	5	4	0579870	4285355	BROOK
07/22/02	4	4	0581210	4287807	INTERMITTENT STREAM
07/22/02	5	4	0579870	4285355	BROOK
07/24/02	8	4	0580271	4283284	SPRING-FED BROOK
07/24/02	8	4	0580117	4283184	SEEP
07/24/02	7	4	0578659	4283008	INTERMITTENT STREAM
07/24/02	8	4	0580271	4283284	SPRING-FED BROOK
07/24/02	8	4	0580117	4283184	SEEP
07/24/02	9	4	0581619	4282393	SKID TRAIL SEEP
07/25/02	1	4	0581956	4298690	SEEP
07/25/02	1	4	0581956	4298690	SEEP
07/25/02	2	4	0584692	4297232	INTERMITTENT STREAM
07/25/02	3	4	0581011	4296507	INTERMITTENT STREAM

07/27/02	6	5	0581709	4284707	WETLAND
07/27/02	6	5	0581918	4284638	SKID RUT POOL
07/27/02	4	5	0582188	4286576	
07/27/02	5	5	0579302	4284101	
07/27/02	6	5	0581918	4284638	SKID RUT POOL
07/27/02	6	5	0581706	4284707	WETLAND FEN
07/30/02	1	5	0581390	4297859	INTERMITTENT STREAM
07/30/02	3	5	0581616	4296464	SEEP

Appendix D. Habitat characteristics for 2002 coverboards (30 May-1 August 2002) including mean % canopy cover measured with a spherical densiometer in 4 cardinal directions from the center of each coverboard station and mean soil temperature (C^{o}) taken with a Taylor^{TM} soil thermometer at depths of 2.5 cm and 10 cm, in random locations within 1 m outside of stations (n=2) and in random locations (n=2) under coverboards, MeadWestvaco industrial forest, Randolph County, WV; compartments 1-3 and 4-6 were sampled preharvest, and compartments 7-9 were sampled postharvest.

DATE	COMP	TRANS	STA	MEAN % CANOPY	MEAN SOIL TEMP OUT (2.5 cm)	MEAN SOIL TEMP UNDER (2.5 cm)	MEAN SOIL TEMP OUT (10 cm)	MEAN SOIL TEMP UNDER (10 cm)
7/2/2002	1	1	1	90	17	17	15	15
7/2/2002	1	1	2	79	22	17	23	20
7/2/2002	1	1	3	80	19	18	18	17
7/2/2002	1	1	4	86	17	16	15	15
7/29/2002	1	2	1	80	21	21	19	20
7/29/2002	1	2	2	84	21	19	20	19
7/29/2002	1	2	3	85	7	19	16	16
7/29/2002	1	2	4	92	22	19	20	19
8/1/2002	1	3	1	1	22	18	19	19
8/1/2002	1	3	2	2	17	19	15	15
8/1/2002	1	3	3	2	19	20	19	18
8/1/2002	1	3	4	2	22	22	20	19
7/2/2002	2	1	1	90	18	16	16	15
7/2/2002	2	1	2	86	19	15	18	18
7/2/2002	2	1	3	88	16	17	16	15
7/2/2002	2	1	4	77	15	16	15	14
7/29/2002	2	2	1	0	19	19	18	19
7/29/2002	2	2	2	89	17	19	16	15
7/29/2002	2	2	3	87	18	18	17	16
7/29/2002	2	2	4	87	18	18	18	18
8/1/2002	2	3	1	88	16	15	16	16
8/1/2002	2	3	2	84	17	16	16	16
8/1/2002	2	3	3	85	18	16	18	17
8/1/2002	2	3	4	79	18	16	16	16
7/2/2002	3	1	1	90	16	18	15	16
7/2/2002	3	1	2	94	20	16	20	19
7/2/2002	3	1	3	94	17	17	16	17
7/2/2002	3	1	4	63	17	17	16	15
7/29/2002	3	2	1	1	18	20	8	18
7/29/2002	3	2	2	96	16	19	16	17
7/29/2002	3	2	3	86	16	20	15	16
7/29/2002	3	2	4	88	19	18	18	19
8/1/2002	3	3	1	91	17	17	17	16
8/1/2002	3	3	2	91	18	16	18	16
8/1/2002	3	3	3	91	19	16	19	18
8/1/2002	3	3	4	94	17	16	17	16

7/1/2002	4	1	1	N/A	14	15	12	13
7/1/2002	4	1	2	N/A	15	16	13	14
7/1/2002	4	1	3	N/A	16	15	14	14
7/1/2002	4	1	4	N/A	17	15	16	15
6/5/2002	4	2	1	N/A	18	16	15	13
6/5/2002	4	2	2	N/A	18	18	15	14
6/5/2002	4	2	3	N/A	19	18	14	14
6/5/2002	4	2	4	N/A	20	18	17	15
6/19/2002	4	3	1	N/A	21	18	15	17
6/19/2002	4	3	2	N/A	16	14	13	13
6/19/2002	4	3	3	N/A	14	13	13	13
6/19/2002	4	3	4	N/A	14	14	13	13
7/1/2002	5	1	1	97	18	18	18	17
7/1/2002	5	1	2	97	19	20	18	19
7/1/2002	5	1	3	91	20	18	18	17
7/1/2002	5	1	4	95	20	20	17	18
6/19/2002	5	2	1	96	15	15	14	14
6/19/2002	5	2	2	97	17	14	15	14
6/19/2002	5	2	3	97	15	15	14	14
6/19/2002	5	2	4	96	16	15	15	15
6/5/2002	5	3	1	95	16	16	14	14
6/5/2002	5	3	2	96	17	15	14	15
6/5/2002	5	3	3	96	18	16	15	14
6/5/2002	5	3	4	96	18	16	16	15
7/1/2002	6	1	1	96	17	16	16	14
7/1/2002	6	1	2	90	18	17	17	16
7/1/2002	6	1	3	92	16	17	15	15
7/1/2002	6	1	4	90	18	17	16	16
6/5/2002	6	2	1	90	17	19	15	15
6/5/2002	6	2	2	93	19	18	16	16
6/5/2002	6	2	3	93	19	18	17	15
6/5/2002	6	2	4	86	19	18	18	16
6/19/2002	6	3	1	89	15	14	14	13
6/19/2002	6	3	2	91	15	15	15	14
6/19/2002	6	3	3	86	16	14	13	13
6/19/2002	6	3	4	87	14	14	14	13

5/30/2002	7	1	1	92	17	17	17	16
5/30/2002	7	1	2	5	21	20	20	20
5/30/2002	7	1	3	0	23	20	20	18
5/30/2002	7	1	4	0	25	19	20	15
6/19/2002	7	2	1	94	16	15	15	15
6/19/2002	7	2	2	10	25	21	20	17
6/19/2002	7	2	3	0	29	23	25	21
6/19/2002	7	2	4	0	25	21	23	20
7/1/2002	7	3	1	91	15	15	15	14
7/1/2002	7	3	2	17	23	21	20	20
7/1/2002	7	3	3	1	24	21	22	21
7/1/2002	7	3	4	0	25	23	22	20
6/3/2002	8	3	1	95	20	22	19	20
6/3/2002	8	3	2	23	28	24	24	19
6/3/2002	8	3	3	0	30	23	23	22
6/3/2002	8	3	4	0	24	24	21	18
6/19/2002	8	2	1	91	15	15	14	13
6/19/2002	8	2	2	3	26	19	21	16
6/19/2002	8	2	3	0	23	20	19	16
6/19/2002	8	2	4	0	24	20	17	16
6/3/2002	8	1	1	92	28	23	19	20
6/3/2002	8	1	2	12	28	22	22	19
6/3/2002	8	1	3	0	29	28	22	20
6/3/2002	8	1	4	0	17	16	15	14
6/3/2002	9	1	1	77	14	14	13	12
6/3/2002	9	1	2	14	22	18	17	15
6/3/2002	9	1	3	0	22	19	17	15
6/3/2002	9	1	4	0	24	20	19	17
6/20/2002	9	2	1	97	15	16	14	14
6/20/2002	9	2	2	36	30	23	18	16
6/20/2002	9	2	3	69	21	21	20	19
6/20/2002	9	2	4	2	35	28	26	20
7/1/2002	9	3	1	95	18	18	16	15
7/1/2002	9	3	2	18	19	18	17	16
7/1/2002	9	3	3	2	20	18	19	19
7/1/2002	9	3	4	0	20	19	19	18

VITA

Born in North Carolina in 1971, Lori Ann Williams was raised in southeast Raleigh where she lived until graduating from Garner Sr. High School in 1989. Lori attended college at Appalachian State University in Boone, North Carolina, where she earned a BS in English, Secondary Education in 1993. After a brief teaching career, she returned to school and graduated with a BS in Wildlife Science in 2000 from Virginia Tech in Blacksburg, Virginia, while working as a technician for the Conservation Management Institute of Virginia Tech and for the Virginia Department of Game and Inland Fisheries. Lori completed her MS in Wildlife Science in the Department of Fisheries and Wildlife Sciences at Virginia Tech in 2004 and is currently employed as a mountain region nongame wildlife biologist with the North Carolina Wildlife Resources Commission in Asheville, North Carolina.

Lori A. Williams