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Movement Patterns and Artificial Arboreal Cover Use of Green Salamanders (Aneides aeneus) in Kanawha County, West Virginia

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Movement patterns and artificial arboreal cover use of Green Salamanders (*Aneides aeneus*) in Kanawha County, West Virginia

Thesis Submitted to
The Graduate College of
Marshall University

In partial fulfillment of the
Requirements for the Degree of
Master of Science
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By

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ABSTRACT

Global amphibian declines have spawned a need for amphibian monitoring studies using standardized sampling techniques for early detection of population declines. The Green Salamander (*Aneides aeneus*) is a declining plethodontid salamander (Family: Plethodontidae) associated with rock outcrops and arboreal habitat. The unique habitat requirements of this species make *A. aeneus* populations particularly susceptible to habitat perturbations. Although primarily associated with rock outcrops, *A. aeneus* morphology and ecology suggest that *A. aeneus* may be highly mobile. High mobility has important implications for habitat management, particularly pertaining to land surrounding rock outcrops. However, few studies have addressed plethodontid movement patterns, which are fundamental to understanding the ecology of a species and provide vital information for conservation initiatives. Thus, I investigated *A. aeneus* movement patterns in Kanawha County, West Virginia. Specifically, my objectives were to 1) use fluorescent powder to quantify daily movement patterns and 2) assess the efficiency of using artificial cover (i.e., burlap) in *A. aeneus* monitoring protocols. Use of fluorescent powder is an effective method of tracking amphibians that involves using a ultra-violet light to illuminate an individual's path. I attached burlap bands to trees in transects within the study area and surveyed for *A. aeneus* seeking artificial cover as they climbed the trunks. I tracked movements of 37 *A. aeneus* and 21 Cumberland Plateau Salamanders (*Plethodon kentucki*). The maximum distance traveled by a single *A. aeneus* within 24 hours was 14.8 m. I used a two-way ANOVA to investigate the effects of species and sex on salamander movement. Species had no significant effect on salamander movement, but sex had a significant effect, with males moving farther than females. Body size of *A. aeneus* was not correlated with distance moved. Season and habitat had no effect on *A. aeneus* movement. After 131 surveys at 6 study sites, I found 4 *A. aeneus* using artificial arboreal cover. Nocturnal surveys were more effective for detecting *A. aeneus* than diurnal surveys. Additionally, area constrained searches detected *A. aeneus* more effectively than transect surveys. Information gathered from this study provides valuable information about plethodontid movement in general, which will assist management of *A. aeneus* habitat.

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CHAPTER 1: PROJECT OVERVIEW AND SITE DESCRIPTION

The First World Congress of Herpetology in 1989 raised an awareness of amphibian decline and loss on a global scale and sparked an intensified interest in amphibian population biology (Alford and Richards, 1999; Corser, 2001). It is now widely accepted that amphibian declines is still a problem (Alford and Richards, 1999). Causes of decline include introduced species, over-collection by researchers, UV-B radiation, chemical contaminants, fungal pathogens, global climate change, and habitat loss and modification (Corser, 2001; Storfer, 2003).

Odum (1992) suggested that the first signs of environmental stress usually occur at the population level, affecting especially sensitive species. When stress produces detectable ecosystem-level effects, the health and survival of the whole system is in jeopardy. Amphibians are especially sensitive to environmental toxins or to changes in patterns of temperature and rainfall due to their highly permeable skin (Alford and Richards, 1999), making them effective indicator species, whose presence, absence, or relative well-being in a given environment is indicative of ecosystem health. Absences or evident declines may be an early warning of more general environmental problems (Storfer, 2003) and this early warning should not be ignored (Odum, 1992). Plethodontid salamanders (Family: Plethodontidae) are good indicators of the health of forest ecosystems, and thus plethodontid declines have alerted ecologists to problems in this ecosystem (Welsh and Droege, 2001).

Corser (2001) stated that a common trend of amphibian declines occurs most often in montane regions. Montane specialists, such as the Green Salamander (*Aneides aeneus*), are vulnerable to habitat loss and climate change due to ecological constraints, such as unique habitat requirements. Corser (2001) surveyed historic populations from a long-term study conducted in the Blue Ridge Escarpment in North Carolina and noted colossal population declines since 1970. Seven historical populations, which were originally surveyed by Snyder (1971), declined by 98% since 1970, from 95 reproductive females to an average of 1.67 between 1990 and 1999 (Corser, 2001). Habitat loss and other factors such as climate change, disease, and overcollection were considered potential contributors to *A. aeneus* declines, but the cause remains unidentified (Corser, 2001; Waldron and Pauley, 2007).

Since the initial documented reports of global amphibian declines in the late 1980s, more details regarding causes of decline have become available, yet there is no simple solution (Storfer, 2003). Even with numerous experimental and monitoring studies, the autecology of amphibians in a natural environment remains poorly understood. Due to their cryptic nature, plethodontids are difficult to study, and thus, we know relatively little about their movements or activities (Alford and Richards, 1999). There is a need to understand movement patterns since they affect, or are affected by many traits of the autecology of a species, including its water and temperature relations, foraging ecology and energetics, mating system, predator response, and interspecific interactions. Movements lead to some costs, such as energy use and exposure to unfavorable conditions and, or predators (Pough et al. 2004). Literature searches on movements lead to home range studies on more common plethodontid species involving mark-recapture methods, many of which indicate that surface movements of these salamanders are limited and that terrestrial bounded plethodontid salamanders are poor dispersers (Ovaska, 1988; Marsh et al. 2004).

Due to the gap in scientific documentation of plethodontid movement patterns, and the amphibian decline crisis, I focused my research on quantifying movement patterns of an understudied montane plethodontid salamander, the Green Salamander (*Aneides aeneus*). Although home range size has not been determined for this species, several mark-recapture studies on linear movement patterns exist (Pauley and Watson, 2005). Linear movements up to 100 m have been documented (Petranka, 1998). A problem with using mark-recapture data for movement patterns, is that the actual movement between recaptures may be underestimated.

Studying movement patterns of *A. aeneus* might provide an extreme example of movement. The morphology of *A. aeneus* suggests a more mobile lifestyle and potentially travels farther than any other plethodontid salamander, but more data are necessary to quantify movement of this species. Bishop (1928) characterized *A. aeneus* as extremely agile with well-developed toe disks that enable them to run with agility. Additionally, this species is tolerant to desiccation (Gordon, 1952), so water balance would not limit movements in the same way as other plethodontids.

My objectives were to 1) use fluorescent powder, an effective method of tracking amphibians, to quantify short term (within 24 h) movement patterns of *A. aeneus* and 2) assess the efficiency of using artificial cover (i.e., burlap) in *A. aeneus* monitoring protocols. I attached burlap bands to trees in transects within the study area and surveyed for *A. aeneus* seeking artificial cover as they climbed the trunks. Currently, there is no standardized technique for monitoring *A. aeneus* populations, so this portion of my study examined a potentially effective standardized sampling method of *A.*

aeneus that, if effective, may be used in population monitoring and potentially detect future declines.

Information gathered from this study provides valuable information about plethodontid movement in general, which will assist in management of *A. aeneus* habitat. Knowing where, when, and essentially how far *A. aeneus* move will provide data for land managers to use when making management decisions regarding land surrounding rocks or trees known to harbor *A. aeneus*.

SPECIES DESCRIPTION:
The Green Salamander *Aneides aeneus* (Cope and Packard)

Primarily confined to the Appalachian Plateau and the Blue Ridge Escarpment, Green Salamanders (*A. aeneus*) are a declining plethodontid species associated with rockface habitats (Petranka, 1998). *Aneides aeneus* are a small- to medium-sized salamander with a brown dorsum that is overlaid with green, lichenlike patches, providing camouflage on rock outcrops (Figure 1) (Green and Pauley 1987). The geographic distribution of *A. aeneus* consists of two main sections that are separated by the Appalachian Valley. The more extensive western section is mainly within the Appalachian Plateau Province from southwestern Pennsylvania to central Alabama; with a more restricted southeastern section centralized on the Blue Ridge embayment (Figure 2) (Gordon, 1952; Bruce, 1968). *Aneides aeneus* inhabit lower elevations within a range of 139 and 1333 m (Green and Pauley, 1987; Johnson, 2002). In West Virginia, *A. aeneus* inhabits central counties of the Appalachian Plateau, from the northern counties of Monongalia and Preston, southwest to the Big Sandy River (Figure 3) (Green and Pauley, 1987; Johnson, 2002).

Aneides aeneus are the only salamanders belonging to the genus *Aneides*, or climbing salamanders, in the eastern United States (Green and Pauley, 1987; Wilson, 2003). This genus includes 6 species. The other members of *Aneides* occur in the western United States, and include Clouded Salamanders (*A. ferreus*), Black Salamanders (*A. flavipunctatus*), Sacramento Mountain Salamanders (*A. hardii*), Arboreal Salamanders (*A. lugibris*) and Wandering Salamanders (*A. vagrans*). Spickler et al. (2006) found *A. vagrans* in the canopy of red-wood forests year round. Bishop

(1928) considered *A. aeneus* as weakly arboreal, yet Waldron and Humphries (2005) found *A. aeneus* as far as 21 m up a tree.

Aneides aeneus inhabit one of the most specialized and desiccation-tolerant niches of any eastern salamander. They have morphological adaptations (e.g., dorsoventrally flattened body and well-developed toe disks) that allow them to live in unique habitat (Bishop 1928, 1943). *Aneides aeneus* occupy crevices in relatively moist, but not wet, heavily shaded (Hulse et al. 2001) rock outcrops that are composed of limestone (Walker and Goodpaster 1941), sandstone, granite, and schist (Netting and Richmond 1932) surrounded by mature hardwood forests (Corser 2001; Waldron and Humphries 2005). *Aneides aeneus* have been documented to seek refuge beneath pieces of rock in fairly dry situations (Bishop 1943). During spring, *A. aeneus* come out of deep rock cervices, which serve as hibernacula, and disperse to other rock crevices and the surrounding forest (Jensen et al. 2008).

Aneides lugubris are desiccation tolerant and are among the last salamander to seek refuge to evade desiccation (Petranka, 1998; Staub and Wake, 2005). Like its congener, *A. aeneus* are tolerant to desiccation and can withstand water-loss of up to 30% its body mass (Gordon, 1952). This adaptation allows them to live in drier rock habitat that may be unsuitable for other terrestrial salamanders. Also, desiccation tolerant salamanders are adapted to live in arboreal habitat. Whenever a salamander climbs above the forest floor, it is exposed to air movement that may have a desiccating effect (Jaeger, 1978). Morphologically adapted and desiccation tolerant salamanders, such as *A. aeneus*, can climb trees using their well-developed toe disks and withstand evaporative water-loss to air.

Like other salamanders, *A. aeneus* are predators. Prey items include snails, slugs, spiders, and small insects (Gordon, 1952). *Aneides aeneus* consume insects such as coleopterans, dipterans and hymenopterans (Lee and Norden, 1973; Canterbury and Pauley, 1990).

During the breeding season, males and females pair together in rock crevices. This courtship may take place during anytime within the warmer months of the year, but most mating occurs in May and June (Petranka, 1998). In West Virginia, *A. aeneus* mate in late May and early June, and potentially again in September and October, based reproductive characteristics observed on some males in the fall (Canterbury and Pauley 1994). Females have a biennial egg-laying cycle (Canterbury and Pauley, 1994) and females lay clusters of unpigmented eggs in crevices tied together by mucus (Green and Pauley, 1987). Canterbury and Pauley (1994) found 12 -27 eggs in a clutch and that females stayed with their eggs for 82 to 90 days until hatching and remained with hatchlings for months. Northern West Virginia populations take 7 to 8 years to reach reproductive maturity (Waldron and Pauley, 2007). Species that require more time to reach sexual maturity have life histories that can increase a species' susceptibility to population declines and ultimately extinction (Webb et al. 2002; Waldron and Pauley, 2007).

Aneides aeneus has a patchy distribution and is generally uncommon throughout most of its range (Petranka, 1998). The U.S. Fish and Wildlife Service (USFWS) listed *A. aeneus* as a species at risk in response to the species' unique habitat requirements (e.g., rock outcrops and arboreal habitat in mature eastern forests), slow life history (i.e., delayed maturation and biennial reproduction), and documented populations declines

(Waldron and Humphries 2005). *Aneides aeneus* have a global rank of G3/G4. NatureServe (2009), a non-profit conservation organization, defines this rank as a combination of “20 to 100 documented occurrences, either very rare or local throughout its range or found locally in a restricted range” (G3), and “common and apparently secure globally, though it may be rare in parts of its range, especially at the periphery” (G4). The International Union for Conservation of Nature and Natural Resources (IUCN) lists *A. aeneus* as near threatened with a declining population trend (IUCN 2009). It has been a candidate for protection under the Federal Endangered Species Act (Jensen et al. 2008). It is listed as critically imperiled, imperiled, or vulnerable in 10 of the 13 states in which it inhabits (Waldron and Humphries 2005). The West Virginia Wildlife Diversity Program considers *A. aeneus* as a species of concern, with an S3 rank, signifying 20 to 100 known occurrences.

Since *A. aeneus* are cryptic and difficult to study (Juterbock, 1998; Waldron, 2000), several aspects of natural history, such as longevity and movement remains unknown or poorly understood. *Aneides aeneus* longevity is not clearly defined and is estimated at 3 to 10 years or longer. Additionally, the home range size of *A. aeneus* is unknown (Pauley and Watson, 2005). Previous movement studies involved mark-recapture techniques and examined linear movement patterns, which failed to provide.the same type of information gathered when following an individual’s path. Movement patterns affect, or are affected by many traits of a species’ biology, including its water and temperature relations, foraging ecology, mating system, predator response, and interspecific interactions (Pough et al. 2004). Gathering data on *A.*

aeneus short term movement patterns would shed light on these poorly understood traits.

SITE DESCRIPTION

I conducted my research at Kanawha State Forest in Kanawha County, West Virginia. I constructed a circular plot (50 m diameter) at each of six study sites between March and May 2009 (Figure 4). I centered 3 of the sites on an emergent rock that was known to harbor *A. aeneus*, based on previous surveys. I centered the remaining 3 sites at randomly selected locations by taking a random bearing along trails. Sites that were devoid of emergent rocks will be referred to as “non emergent-rock sites” and those centered on emergent rocks, which will be referred to as “emergent-rock sites.” The emergent-rock sites contained sandstone conglomerate rocks. All sites were in mixed-deciduous forests on northwest sloping hillsides. Since *A. aeneus* have been documented to move $\geq$ 100 m, (Gordon 1952; Gordon 1961; Waldron and Humphries, 2005), I located my study plots at least 100 m apart, which decreased the probability that individuals moved between plots.

Site 1: Polly Hollow Trail A

Site 1 was located along Polly Trail (Figure 5). This site was centered on an emergent rock on which I had detected *A. aeneus* during preliminary surveys for study plots. At an elevation of 256 m, Site 1 was located on a northwest facing hillside (Figure 5). A yellow birch (*Betula alleghaniensis)* with a 26 cm diameter at breast height (DBH) was growing on top of the moss-covered, emergent rock. This site also had a cluster of small emergent rocks that lacked suitable crevices for salamander refuge. Average canopy cover was 93.06%.

Site 2: Polly Trail B

Site 2 was also along Polly Trail (Figure 7), and was centered on an emergent rock on which I detected Aa during preliminary surveys. At an elevation of 263 m (Figure 7), Site 2 contained three moss-covered, emergent rocks situated on a northwest-facing hillside (Figure 8-10). A *B. alleghaniensis* with a 28 cm DBH was growing on top of one emergent rock. Average canopy cover at Site 2 was 94.05%.

Site 3: Davis Creek Trail

Site 3 was located along Davis Creek Trail (Figure 11) and was chosen based on observations of *A. aeneus* seeking within a crevice on a moss covered, emergent rock during an April 2009 survey. This site, located at an elevation of 229 m, had one emergent rock situated on a northwest-facing hillside (Figure 12). Average canopy cover at Site 3 was 93.12%.

Site 4: Polly Trail C

Site 4 did not contain emergent rocks (i.e., a non-emergent rock site). Site 4 was located along Polly Trail (Figure 13) on a northwest-facing hillside. The site was located at an elevation of 301 m, and canopy cover was 88.96%.

Site 5: Lindy Trail

Site 5 was a non-emergent rock site, located along Lindy Trail (Figure 15) on a northwest-facing hillside. At an elevation of 259 m, Site 5 lacked emergent rocks and canopy cover was 93.12%.

Site 6: White Hollow Trail

Site 6 was a site free of emergent rocks, located along White Hollow Trail (Figure 16) on a north-west facing hillside. At an elevation of 260 m, Site 6 had no suitable emergent rocks and canopy cover was 91.91%.

VEGETATION ANALYSES OF SITES

INTRODUCTION

Aneides aeneus occupy rocks surrounded by mature hardwood forests (Corser 2001; Waldron and Humphries 2005). A continuous mature forest encompassing rock habitat is important for *A. aeneus* because Waldron and Humphries (2005) observed seasonal arboreal activity of *A. aeneus*, during which they left rock habitat and moved to the surrounding trees. *Aneides aeneus* seem to prefer American Beech (*Fagus grandifola*) and trees with rough bark that provide crevices for refuge, such as White Oak (*Quercus alba*) (Waldron and Humphries, 2005). Since *A. aeneus* use arboreal habitat (Wilson, 2003; Waldron and Humphries, 2005), I quantified tree composition at each study site. Differences in tree composition between sites may influence *A. aeneus* populations, due to their habitat requirements of heavily shaded rock outcrops surrounded by hardwood forests (Hulse et al. 2001).

METHODS

I developed twelve 5 m X 5 m subplots in each of my study sites, which allowed me to sample vegetation at a scale of 300 m^2 (0.03 hectare) at each site (Figure 19). Within each plot I took the canopy cover 3 times (at the middle and both ends of the plot) using a spherical densitometer and averaged the values. Also, within each plot, I identified every tree to species and measured tree diameter at breast height (DBH) using a Biltmore stick. I included trees with a DBH $\geq$ 4 cm in my sampling. I calculated basal area (m^2 ha^{-1}) for each tree, species frequency, species dominance (basal area) (m^2 ha^{-1}), and species density (stems ha^{-1}). I calculated relative values of species frequency by dividing the species frequency by the total frequency of all species combined and expressing the result as a percentage. I calculated relative species dominance (basal area) (m^2 ha^{-1}) and relative species density (stems ha^{-1}) the same way. I calculated the importance value for every tree species at each study site by summing the values of relative species frequency (plots), relative species dominance (basal area) (m^2 ha^{-1}), and relative species density (stems ha^{-1}). Importance values relate the relative contribution of a species in a plant community in relation to the nutrients it takes and removes (Stohlgren, 2007). The significance of a tree species to achieve a given importance value shows that it is an important element in a stand (Curtis and McIntosh, 1951). Importance value is a value that can be compared across sites by examining differences in these values between species, across sites.

RESULTS

Table 1 shows the frequency, density, basal area, relative frequency, relative density, relative basal area, and importance value for each tree species at all my sites. Both Site 1 (Polly Trail A) and Site 3 (Davis Creek Trail) had American Beech (*Fagus grandifola*) as the tree species with the greatest importance value (74.63 and 102.22, respectively). American Basswood (*Tilia americana*) was the tree species with the greatest importance value for Site 5 (Lindy Trail) and Site 6 (White Hollow Trail) at 107.16 and 105.05, respectively. The tree species with the highest importance value at both Site 2 (Polly Trail B) and Site 4 (Polly Trail C) was Eastern Hemlock (*Tsuga canadensis*) (121.48 and 85.94, respectively).

CHAPTER 2: GREEN SALAMANDER (*ANEIDES AENEUS*) MOVEMENT PATTERNS

INTRODUCTION

Information on movement patterns of individuals is vital to understand the ecology of a species (Madison and Farrand, 1998). Movement patterns are important because they affect, or are affected by many traits of a species' autecology, including its water and temperature relations, foraging ecology and energetics, mating system, predator response, and interspecific interactions. Movements lead to costs, such as energy use and exposure to unfavorable conditions or predators (Pough et al. 2004). Movement patterns generally pertain to where, when, and how far an individual moves. In contrast to other vertebrates, the movements of amphibians are inadequately documented (Madison and Farrand, 1998). Several salamander movement studies focused on pond breeding taxa, such as Eastern tiger salamanders (*Ambystoma tigrinum*) (Madison and Farrand, 1998), Marbled Salamanders (*Ambystoma maculatum*), Blue-Spotted Salamanders (*Ambystoma laterale*) and Red-Spotted Newts (*Notophthalmus viridescens*) (Mazerolle, 2001). Few studies have addressed plethodontid movement at all, due to the difficulty of finding and studying this particular family of terrestrial salamanders.

While information about plethodontid movement patterns is limited, there have been published accounts of movement (including home range) for numerous species, including, Eastern Red-backed Salamanders (*Plethodon cinereus*, Western Red-backed Salamanders (*Plethodon vehiculum*), Jordan's salamanders (*Plethodon jordani*), Slimy Salamanders (*Plethodon glutinosus*), and Northern Dusky Salamanders (*Desmognathus fuscus*). Home range is defined as the area used for the acquisition of resources such as food, mates, basking sites, or shelter (Pough et al. 2004). *Plethodon vehiculum* maintains relatively small home ranges (i.e., approximately 3 m, but up to 8.5 m), based on movements between recaptures of marked individual salamanders (Ovaska, 1988). *Plethodon cinereus* home ranges average 10-25 m^2 (Kleeberger and Werner, 1982; Marsh et al. 2004), which is larger than home ranges of *P. jordani* (11.47 m^2 [males], 2.81 m^2 [females] and 1.72 m^2 [juveniles]) and *P. glutinosus* (14.39 m^2 [males], 6.52 m^2 [females] and 7.53 m^2 [juveniles]) (Merchant, 1972). Some male salamanders are floaters (T.K. Pauley, pers. communication) and may move farther to establish a new territory or for mate searching (Pough et al. 2004).

Since terrestrial plethodontids do not need aquatic habitat for breeding, they are typically sedentary, with smaller home ranges and constrained dispersal ability (Marsh et al. 2004). Limited movement might reflect activity patterns of terrestrial amphibians, which are heavily influenced by maintaining water balance and facilitating gas exchange because their permeable skin has little prevention of evaporative water loss (Keen 1984).

Aneides aeneus morphology and desiccation tolerance suggest a more mobile lifestyle, and thus *A. aeneus* potentially travels farther than any other plethodontid salamander. Specifically, *A. aeneus* are extremely agile and capable of leaping several times its own length (Bishop, 1928). *Aneides aeneus* is dorsoventrally flattened with a prehensile tail that enables them to maneuver (Cupp, 1991). Also, *A. aeneus* have toe disks that are well developed, enabling them to run with agility on vertical surfaces (Bishop, 1928). Diefenbacher (2008) compared phalanx histology between *A. aeneus*, *P. kentucki*, and the Northern Slimy Salamander (*P. glutinosus*). He found that *A.*

aeneus possessed the greatest phalanx curvature, as well as the largest dermal thickening, concentrated around the end of the terminal phalanx, and suggested that characteristics are adaptations for climbing. Additionally, this species is tolerant to desiccation and can lose up to 30% of its body weight in water (Gordon, 1952), so water balance would not limit movements in the same way as other plethodontids. Thus, *A. aeneus* might offer insight into upper-end mobility relative to other plethodontids, which do not possess such unique adaptations.

Although *A. aeneus* was considered to be sedentary (Gordon, 1952), t movements of up to 100 m have been detected (Gordon, 1952, 1961; Corser, 2001). Gordon (1961) found that displaced *A. aeneus* typically return to original crevices, traveling as far as 8.84 m, but the return route was unknown.

The possibility of greater mobility in comparison to other plethodontids warrants greater care when making management decisions. Species management plans that apply to plethodontids with smaller home ranges will not apply to *A. aeneus*. Knowing where, when and how far *A. aeneus* move is vital information that land managers can use for conservation initiatives.

More studies are necessary to determine the movement patterns of *A. aeneus*, since little information is available on this topic for this narrowly distributed, declining species. The objective of this study was to assess short-term (i.e., 24 hr) movements for *A. aeneus*. To compare movement across taxa, I tracked another plethodontid encountered, namely, Cumberland Plateau Salamanders (*Plethodon kentucki*). *Plethodon kentucki* is a good species to compare movement because they lack the unique adaptations of *A. aeneus* (i.e., dorsoventrally flattened body, expanded toe discs, and desiccation tolerance) and their home range is not defined, only suggested to be small (Pauley and Watson, 2005). Also, Canterbury (1991) found competition between *P. kentucki* and *A. aeneus* and additional field data suggested that *P. kentucki* may compete for rock crevices with *A. aeneus* where their respective ranges overlap in West Virginia (Diefenbacher, 2008). Differences in movement between these species may affect interspecific competition by allowing *A. aeneus* to exploit resources with their greater capacity to move.

I used fluorescent pigment powder tracking, in which powder applied to an individual was shed as the animal moved; leaving a path that could be traced with a portable ultraviolet light (Graeter and Rothermel, 2007). The powder temporarily adhered to skin making tracking movements possible without using potentially problematic implant radio transmitters, which can be harmful for a salamander the size of *A. aeneus* (Orlofske et al. 2009). My study is the first to collect short term movement pattern information on *A. aeneus* in West Virginia. Specifically, I used pigment powder tracking to: 1) compare movements between *A. aeneus* and *P. kentucki*, to see if *A. aeneus* is more mobile as a result of their unique adaptations, 2) test for influence of sex on distance moved, 3) assess the effect of season (spring [May and June], summer [July and August] and Fall [September and October]) on *A. aeneus* movement, 4) test for influence of habitat (rock [out on rockface], crevice [in rock crevice], and tree) on *A. aeneus* movement, and 5) test for influence of size (SVL) on *A. aeneus* movement.

MATERIALS AND METHODS

Study Area/Design

I conducted my research in Kanawha County, West Virginia. I constructed a circular plot (50 m diameter) at each of six study sites between March and May 2009 (Figure 4). I centered 3 of the sites on an emergent rock that was known to harbor *A. aeneus*, based on previous surveys. I centered the remaining 3 sites at randomly selected locations by taking a random bearing along trails. Sites that were devoid of emergent rocks will be referred to as “non emergent-rock sites” and those centered on emergent rocks, which will be referred to as “emergent-rock sites.” The emergent-rock sites contained sandstone conglomerate rocks. All sites were in mixed-deciduous forests on northwest sloping hillsides. Since *A. aeneus* have been documented to move ≥ 100 m, (Gordon 1952; Gordon 1961; Waldron and Humphries, 2005), I ensured that study plots were located at least 100 m apart, which decreased the probability that individuals moved between plots. This manuscript is part of another study on monitoring techniques (i.e., Chapter 3: Artificial Arboreal Cover Use Assessment) that involved attaching burlap to trees and conducting transect surveys to assess the efficacy of detecting *A. aeneus*.

Salamander Surveys

I used area-constrained searches of all available habitat (e.g., cover objects, trees, and emergent rocks) within each circular plot to capture salamanders. I used a flashlight to search crevices in rocks and trees during diurnal and nocturnal searches. I calculated person hours to quantify survey effort and adjusted this value when I found a salamander on a rock, under burlap or on a tree by subtracting 10 minutes from the survey’s person hours, based on the amount of time it took to process a single salamander. I coaxed inaccessible salamanders from crevices with a blunt tipped stick. Prodding was usually ineffective because it caused salamanders to retreat deep within crevices, which resulted in no capture. I conducted arboreal searches from the ground using binoculars (Waldron and Humphries, 2005).

I sexed *A. aeneus* by examining jaw musculature. I considered salamanders with enlarged jaw musculature to be males (T.K. Pauley, pers. communication). I sexed *P. kentucki* by the presence of secondary sexual characteristics, (i.e., mental gland) (Petranka, 1998). If I could not accurately sex a salamander I considered it non-reproductive female (Waldron and Humphries, 2005). I used a Vernier caliper to measure captured salamanders for mass (g), snout-vent length (SVL; mm), and total length (TL, mm). I placed *A. aeneus* into one of three size classes according to SVL, including adults (>44.5 mm), subadults (29.5–44.4 mm), and juveniles (<29.4 mm) (Waldron and Humphries, 2005).

Color patterns of some salamanders are unique to each individual and are analogous to fingerprints. These patterns can be recorded with photographs in a technique called pattern mapping (Donnelly et al. 1994). For individual recognition, I used a digital camera to record the dorsal pattern of each individual as a mark-recapture technique (Waldron and Humphries, 2005).

I included observational data from captures in my results to provide information on *A. aeneus* and *P. kentucki* populations throughout the study period.

Quantifying Movement Patterns

I used fluorescent pigment powder (ZQ-11 Aurora Pink, DayGlo Color Corp, Cleveland, Ohio), which is an effective, noninvasive technique used to track the movements of amphibians (Rittenhouse et al. 2006) to track daily movements of *A. aeneus* and *P. kentucki*. I dipped the ventral posterior three-quarters of each individual into powder (Blomquist and Hunter, 2007) so that I could follow movements using a handheld ultraviolet light (Spectroline Battery Operated Ultraviolet Model UV-4B Lantern, Spectronics Corporation, Westbury, New York), which illuminated the powder and displayed the trail of the salamander. To allow salamanders sufficient time to move, I returned within 24 hours after release to track paths (Graeter and Rothermel, 2007). Movement patterns were traced with a string, and the amount of string used was measured and recorded to attain total distance moved. I recorded the type of substrate from which each salamander was collected, as well as the substrate to which it was tracked. I categorized substrate into rock (out on rockface), crevice (in rock crevice), and tree. I recorded collection locations with a hand held GPS receiver (Garmin etrex Venture HC, Garmin International, Inc, Olathe, Kansas).

Statistical Analyses

I performed all statistical analyses using SAS (SAS Institute, Inc., Cary, North Carolina). Due to recaptures of 4 individuals, the data set included more than one observation per individual (average # of observations per individual = 1.12). I never tracked the same individual on the same night, and I therefore kept these observations to increase sample size (total N = 45).

Intrinsic Factors Affecting Movement

To determine if there was an effect of species and sex (for observations of which sex was known) on daily movement distance, I conducted a 2-way ANOVA. To comply with ANOVA requirements of normally distributed data, I transformed distance using a square root transformation**.** I used a Tukey test for post hoc multiple comparisons of species and sex. To determine if there was a relationship between *A. aeneus* size (SVL) and distance, I performed a correlation analysis.

Extrinsic Factors Affecting Movement

I only examined extrinsic effects on *A. aeneus* movement for two reasons. First, *P. kentucki* and *A. aeneus* use different habitats and thus cannot be combined with *A. aeneus* movement in an ANOVA model to assess habitat effects. And second, I did not have enough data for *P. kentucki* to conduct a similar ANOVA.

I used a 1- way ANOVA to test for an effect of site on *A. aeneus* movement to determine if I could combine observations across sites. Next, I conducted a 2- way ANOVA to test for an effect of season and habitat on *A. aeneus* daily movement distance. I did not include 'sex' in this model because I only had 6 males, which would have significantly reduced the sample size (i.e., I would have to throw out all of the observations in which sex was unknown).and the first analysis already demonstrated that males move greater distances than females (see Results). Season and habitat were categorical variables. I categorized season based on the natural history of *A. aeneus* and created 3 levels; spring, summer, and fall, which were not based on calendar year. Since *A. aeneus* breeds and deposits eggs in May and June, I compiled all of my observations from this time into "spring". I considered all July and August observations as the season "summer" because eggs hatch and females can be difficult to find during this time. I grouped any September and October observations into the season, ‘fall’ to mimic Canterbury’s fall aggregation observations (Canterbury, 1991). Thus, ‘Season’ had 3 levels – spring, summer, and fall. “Habitat1” indicates the substrate on which I tracked the individual. “Habitat2” indicates the substrate to which I tracked the individual. I categorized habitat (substrate in which I found *A. aeneus* or that they moved into) into 3 habitat types, i.e., rock (out on rockface), crevice (in rock crevice), and tree.

RESULTS

Captures

I performed 121 salamander surveys between 12 May 2009 and 11 November 2009. I tracked daily movement patterns of 37 *A. aeneus* and 21 *P. kentucki*. As shown in Figure 20, the amount of captures during surveys varied throughout the study period. I tracked most *A. aeneus* in June (13) and October (13). I tracked *P. kentucki* in May (11). In August, I was unable to find any salamanders to track during area constrained surveys, however I found 4 *A. aeneus* individuals during a transect survey for the Artificial Arboreal Refuge Assessment portion of my study (refer to Chapter 3). I included these individuals in my movement pattern data.

Tables 2 and 3 list morphometric data for all *A. aeneus* and *P. kentucki* individuals captured. I was only able to capture *A. aeneus* at Sites 1-3, i.e., my emergent rock sites. Although I found no reproductive *A. aeneus* during the study period (Table 2), I found two *A. aeneus* females guarding nests in crevices at Site 2 (Figure 23) on 23 June and 28 June 2009. I first observed 2 hatchlings (Figure 24) on a rock face at Site 2 on 4 October 2009. In contrast, I encountered 4 reproductive *P. kentucki* males (Table 3), but found no gravid females, eggs or young. Figure 21 depicts the number of individuals within each size class tracked and recaptured for both *A. aeneus* and *P. kentucki*. I tracked and recaptured all size classes of *A. aeneus*. I tracked juveniles and adults of *P. kentucki* but attained no recaptures. As demonstrated in Figure 22, I only captured *A. aeneus* at Sites 1-3, my rock outcrop sites. I captured *P. kentucki* at both rock outcrop sites (Sites 1 and 2) and non-rock outcrop sites (Site 4 and 5). No individuals moved from one site to another, but *A. aeneus* moved between emergent rocks within Site 2 (all rocks were within 3 m of each other). I did not find any tracked individuals on rock outcrops located outside of my sites.

Tables 4 and 5 list the movement patterns of *A*. *aeneus* and *P. kentucki* individuals, respectively. One immature *A. aeneus* was recaptured 4 times (ID # 8). The largest distance any individual moved was 1476 cm, an immature *A. aeneus* (ID# 25) that moved from a rockface to a *B. alleghaniensis* tree, grown on top of the associated rock. I tracked 3 *A. aeneus* individuals on trees up the trunks until I could no longer illuminate the trail with my handheld UV-light. One *A. aeneus* female moved 580 cm from a *F. grandifola* to the ground. An *A. aeneus* female moved 187.2 cm from a rock crevice to a *B. alleghaniensis*, grown on top of the associated rock. An A. aeneus subadult moved Only 1 adult *P. kentucki* moved 425.2 cm to a tree (Table 5). One female *P. kentucki* was found in a lower rock crevice, but did not move (ID #21).

Intrinsic Factors Affecting Movement

Aneides aeneus males moved an average distance (transformed) of 19.79 cm, in contrast to the average distance (transformed) of *A. aeneus* females, 14.13 cm (Table 6). *Plethodon kentucki* males and females moved an average transformed distance of 16.38 cm and 10.40 cm, respectively. Results of the two-way ANOVA were significant ($F = 3.80$, $df = 3$, $p = 0.0186$; Table 7) indicate that while there was a significant effect of sex ($F= 7.97$, $df = 1$, $p < 0.01$), there was no effect of species ($F= 2.98$, $df = 1$ $p > 0.05$) and no effect of interaction between species x sex interaction ($F=0.00$, $df = 1$, $p > 0.05$). Males (average = 18.08 cm) moved significantly farther (stats?) than females (Average = 12.35). There was no correlation between SVL and distance ($r = 0.2056$, $p = 0.1754$).

Extrinsic Factors Affecting A. aeneus Movement

There was no significant effect of site on movement (F = 0.90, df = 2, p = 0.4132), thus I lumped combined all *A. aeneus* observations in the subsequent analyses. Season had no significant effect on movement (F = 1.82, df = 2, p > 0.05). Habitat also had no significant effect on movement (F = 2.73, df = 2, p > 0.05). There was no effect of season x habitat interaction (F=0.66, df = 3, p > 0.05).

DISCUSSION

Captures

I captured the most *A. aeneus* at Site 2, which had the most emergent rocks out of my 3 emergent rock sites, which contained many crevices, although I did not quantify this. Such a set of rocks with many crevices could support a large population of *A. aeneus*, as compared to other sites. Waldron (2000) also observed more individuals at a relatively large rock outcrop with many crevices and inferred that the size and crevice number of such a rock allowed the inhabitance of more salamanders.

I did not find any *P. kentucki* from late June until individuals emerged early October. Bailey (1992) found that seasonal activity was correlated with soil moisture, as opposed to air temperature, soil temperature, air relative humidity, or soil pH. Such an underground retreat during the summer months of my study period is most likely due to seasonal changes in soil moisture, which was not quantified during this study. Some populations in Kentucky are active throughout the summer during periods of rainy weather (Petranka, 1998), but I did not find this to be true for populations at Kanawha State Forest. I found one female *P. kentucki* adult in a lower rock outcrop crevice, which showed no movement from the crevice. I did not find any *P. kentucki* in crevices near the tops of rock outcrops, like Canterbury and Pauley (1991) observed. My observations coincide with observations of vertical stratification by Waldron (2000) in which *P. glutinosus*, a slimy salamander similar to *P. kentucki*, occupied lower crevices compared to *A. aeneus*. Such stratification may be due to the variable climbing ability among salamander species (Cliburn and Porter, 1987).

The abundance of *A. aeneus* in June and October mirrors breeding activity and seasonality. I captured immature *A. aeneus* throughout the breeding period (May and June) but more adults were tracked when the breeding season commenced. As in my study, Waldron (2000) captured sexually immature individuals throughout the breeding period since individuals of this size class do not establish a territory and move around freely (Canterbury, 1991).

I did not find many *A. aeneus* during the summer months. The inability to find *A. aeneus* for periods is common for researchers studying this species. After a five-year mark-recapture study, Juterbock (1998) declared that the efficacy of survey efforts for this species is minimal due to the inaccessibility of *A. aeneus* for elongated periods. *A. aeneus* becomes less active from mid-June to late August in central West Virginia and can be difficult to find on rock outcrops, even where known to be prevalent (Pauley, 2005). Waldron (2000) observed changes in *A. aeneus* activity during summer months and found *A. aeneus* activity at their lowest activity level in July at her study area in Randolph County, West Virginia. She also witnessed a population crash, with the population size below 10 individuals for the duration of the study period until October 1999.

Despite a period of not finding *A. aeneus* via area-constrained searches, I did not witness such a crash, since I began capturing individuals again in September and October. Waldron (2000) conducted rock and ground searches for salamanders within her study area and used pitfall arrays to capture salamander movement between rocks. The study focused on rock dwelling salamanders and therefore surveys did not take into account the arboreality of *A. aeneus*. Perhaps more *A. aeneus* individuals were using arboreal habitat and subsequently overlooked when restricting surveys to rock outcrops and the surrounding ground. Sampling bias toward rock outcrops potentially result in researchers failure to notice *A. aeneus* in arboreal habitat during their active season (Waldron and Humphries, 2005).

My results indicate a period of *A. aeneus* seasonal arboreal activity in West Virginia, as observed in a South Carolina population by Waldron and Humphries (2005). Waldron and Humphries (2005) described this period as a time when *A. aeneus* moved from rock outcrops to trees in late March, early April and returned to rock outcrops as colder weather approached, late October early November. Between August and September, I encountered *A. aeneus* on trees, even when no individuals were found on rocks.

Gordon (1952) proposed that adult *A. aeneus* reach their highest numbers on rocks from late October to mid- December. Woods (1968) observed a peak in visible *A. aeneus* populations due to an influx of individuals around the hibernacula and considered this period ideal for census of *A. aeneus* populations. Canterbury (1991) observed a fall dispersal and aggregation period between late September and mid November during which considerable movement by all age classes and sexes took place, with optimal numbers of individuals in October. Waldron (2000) found 3 individuals within her study area during October and associated such a low number with weather conditions since *A. aeneus* retreat to deep crevices as a freezing conditions approach (Gordon, 1952; Cupp, 1991). I witnessed a fall aggregation period at Kanawha State Forest with 13 *A. aeneus* encountered in October, equal to the number found in June. The first frost in my study area took place 17 October. I surveyed my study area until mid- November and encountered only one inaccessible adult *A. aeneus* at Site 1 and an inaccessible immature *A. aeneus* at Site 2 in November. It is possible that most *A. aeneus* retreated into deeper crevices because of the imminent freezing conditions in my study area.

Movement

Although there was no effect of species on daily movement distance, *A. aeneus* had a greater maximum distance moved than *P. kentucki*. *Aneides aeneus* may have a greater capacity to travel longer distances in a shorter period than *P. kentucki*. Bailey (1992) observed a linear distance of 1.32 m of a juvenile *P. kentucki* between recaptures, during which 22 days elapsed. He also observed a linear distance of 1.81 m of a female *P. kentucki* after 14 days between recaptures. My observations of certain *A. aeneus* individuals moving longer distances than other individuals tracked during my study concur with other studies. Several studies recorded larger movement of some *A. aeneus* individuals over other individuals studied. Waldron (2000) observed a 26.5 m linear distance of *A. aeneus* between rock outcrops. Woods (1968) observed males move as much as 31 m. Williams and Gordon (1961) found 2 *A. aeneus* road mortalities more than 15 m away from a rock outcrop. Gordon (1952) studied 26 marked adults and found that while one individual moved 98 m, most moved less than 4 m, causing him to believe *A. aeneus* generally do not have a very large home range.

Home range encompasses the area used by an individual for its acquisition of food, mates, basking sites, or shelter (Pough et al. 2004). Although I kept track of all *A. aeneus* captures, it was difficult to attain enough data via recaptures to estimate home range. Movement patterns of *A. aeneus* are difficult to observe due to the secluded nature of this species (Waldron, 2000). Apparently, rock outcrops and the surrounding forest at my study sites provided enough resources for foraging and mating, as evident by my observations of nests, but the factors that influence long-distance movements of certain individuals remains unknown. One *A. aeneus* subadult moved 14.8 m from mid-wayup a *B. alleghaniensis* when I tracked it and was continuing its journey up the trunk. I also found *A. aeneus* individuals on a *Q. alba* and *F. grandifola*, located 12.1-14.2 m from the associated rock, which shows considerable movement of these individuals compared to others that were tracked. I only recaptured 4 individuals; due to the cryptic nature of this species, I could not attest to where the previously tracked individuals went for the duration of my study period.

Habitat had no significant effect on distance moved by *A. aeneus*. Most *A. aeneus* moved vertically along rockfaces. Typically, individuals emerge from rock crevices at night to forage in the open on rockfaces, particularly during periods of rain (Petranka, 1998; Gordon, 1952, Netting and Richmond, 1932). *Aneides aeneus* has expanded toe tips (Green and Pauley, 1987) and thus, a great ability to climb upward (Cliburn and Porter, 1987), making this species capable of climbing vertically along rock faces. I tracked 6 individuals on trees. Jaeger (1978) found that salamanders that climb plants at night consume a significantly larger volume of prey than others that forage on the forest floor at night**.** *Aneides aeneus'* ability to climb trees might allow them to exploit food that other salamanders cannot reach. Salamanders that climb plants to forage expose themselves to increased water loss to air, causing potential desiccation. Most salamanders climb plants on wet nights and still lose water (Jaeger, 1978). I observed *A. aeneus* movement as far as 5 m up tree trunks, even on dry nights. Such dry conditions and height should be a limiting factor for terrestrial salamander movement but *A. aeneus* are more desiccation tolerant (Gordon, 1952) and capable of such conditions.

Males moved greater distances than females; such a difference in movement is not consistent among *A. aeneus* movement studies and *P. kentucki* movement is understudied to compare to literature. *Plethodon kentucki* is presumably territorial, although this behavior is largely understudied (Petranka, 1998). Waldron (2000) found no significant difference between the mean linear distance traveled by *A. aeneus* males and females. Canterbury (1991) found linear distances between rock outcrops ranging from 2.6 m for 1 female and 16.8 to 49.4 m for 3 males. *Aneides aeneus* males are territorial and aggressively protect home territories in rock crevices (Cupp, 1971, 1980; Canterbury and Pauley, 1991; Petranka, 1998). Female *A. aeneus* guard nests for 82 to 90 days until hatching and remain with hatchlings for 3 to 5 months (Cupp, 1991; Canterbury and Pauley, 1994). Therefore reproductive female movement is limited from mid-May through September, along with their detectablity by researchers since they are more hidden. Woods (1968) stated that most of the breeding season is spent by reproductive *A. aeneus* females in egg laying and guarding of the young and they are more sedentary than males and immatures. Non-reproductive female movement may not be as limited as reproductive females, and since females have a biennial egg laying cycle in West Virginia (Canterbury and Pauley, 1994) the amount of detectable females (i.e., females that are not guarding nests or brooding young) along with their distances moved may vary yearly. *A. aeneus* males do not share such a parental investment and can move freely once courtship is complete (Woods, 1968).

Although *A. aeneus* activity fluctuated with the breeding season, there was no significant effect of season on movement. This lack of an effect demonstrates that seasonal shifts in temperature and/or moisture may not affect movement in this species, so another variable such as food availability, which was not quantified during this study, may be affecting movement. The distribution of food may make *A. aeneus* move to other habitats (i.e., tree canopy) which would limit *A. aeneus* detectability.

Fluorescent pigment powder was an effective method to track *A. aeneus* and provided data on individual movement patterns. However, several salamander trails that faded due to moist conditions and damp substrate could not provide the true distance of individuals tracked. Additionally, trails that led up trees were only illuminated as far as the UV light could not reach so I resorted to using a pole with my UV lamp attached to track paths greater distances up trees. Waldron and Humphries (2005) suggested conducting tree climbing and canopy searches to survey *A. aeneus* in arboreal habitat. Such a method would have more accurately quantified the true distance of *A. aeneus* tracked up a tree and out of reach, along with possibly finding more salamanders during an area constrained search. Canopy searches may yield more *A. aeneus* captures, especially during the summer months when it is difficult to find them on rock outcrops.

My data offer a glimpse into 24 h movement of *A. aeneus* and *P. kentucki* and afford information that mark-recapture studies fail to provide. Mark-recapture studies do not supply data on movement in between captures and linear distance does not accurately quantify movement. In my study, *A. aeneus* moved a mean distance of 2.45 m (females, N=14), 4.37 m (males, N=6), and 4.80 m (immatures, N=25) within 24 h and no individual ever moved in linear patterns. These values are comparably larger than average distances for size classes resulting from previous mark-recapture studies. Waldron (2000) found mean linear distances of 1.86 m (females), 3.18 m (males) and 3.34 (immatures) with elapsed time between recaptures ranging from 1 day to 134 days. She recaptured a male within 1 day and observed a distance traveled of 2.89 m. Movement within 1 day is more informative than movement during a varying time span. For *P. kentucki*, I observed a mean distance of 1.41 m (females, N=13), 2.79 m (males, N=6), and 1.11 m (immatures, N=2) within 24 h. Bailey (1992) observed a linear distance of 1.32 m of a juvenile *P. kentucki* and 1.82 m of a female *P. kentucki* between recaptures, during which 22 and 14 days elapsed, respectively.

My short term movement data for both *A. aeneus* and *P. kentucki* indicate that previous research using mark-recapture methods underestimate plethodontid movement. The possibility that plethodontid salamanders may move more than previously quantified has important conservation implications. Species that move greater distances are more vulnerable to unfavorable environmental conditions and predators. Additionally, species that move large distances need more continuous habitat and are therefore more vulnerable to habitat loss and modification (Pough et al. 2004). Fluorescent pigment powder tracking should be used to quantify short term movement of other plethodontid salamanders and attain a potentially more accurate quantification of movement.

ARTIFICIAL REFUGE ASSESSMENT

INTRODUCTION

Aneides aeneus populations in the Blue Ridge Escarpment of North Carolina suffered a 98% decline between 1970 and 1990, based on long-term monitoring of7 historical populations (Snyder 1971, Corser 2001). Long-term monitoring is often required to effectively detect population declines. Even though *A. aeneus* is considered a declining species, there are currently no standardized techniques for monitoring their populations. Surveys for *A. aeneus* typically include diurnal and nocturnal visual searches of rock outcrops and occasionally arboreal habitat (e.g., Canterbury 1991, Corser, 2001, Waldron and Humphries, 2005).

Terrestrial salamanders are difficult to monitor due to their small size and fossorial nature. Drift fences and pitfall traps are commonly used for surveys (Houze and Chandler, 2002), but this technique is ineffective for surveying *A. aeneus*. Waldron (2000) attempted to use drift fences and pitfall traps around rock outcrops containing *A. aeneus* populations in Randolph County, West Virginia, but was unable to capture a single *A. aeneus* on the forest floor.

Using artificial cover objects, such as coverboards, is another way of monitoring amphibians (Fellers and Drost, 1994; Houze and Chandler, 2002). Amphibians take cover beneath surface objects (e.g., coarse woody debris and rocks), therefore artificial/natural cover objects can be used for sampling these taxa. By setting out a standardized set of cover objects, amphibian assemblages can be surveyed under a constant, identical amount of cover. Coverboards are designed to provide a suitable microclimate to act as refuge for terrestrial salamanders that are active at the surface of the forest floor (Fellers and Drost, 1994; Houze and Chandler, 2002). However, researchers' seldomly observe *A. aeneus* on the forest floor (Snyder, 1991), and *A. aeneus* activity is associated withrock outcrops and arboreal habitats (Waldron and Humphries, 2005).

Aneides aeneus are active on trees and use rough bark or holes in tree trunks as refuge (Wilson, 2003; Waldron and Humphries, 2005). Similar to the use of coverboards on the forest floor, attaching artificial cover to trees around rock outcrops might offer an effective technique for sampling populations of *A. aeneus* (Thigpen, 2006). The objective of this study was to assess the effectiveness of using artificial arboreal cover to sample *A. aeneus*. Specifically, I used burlap bands that were tied around tree trunks to sample *A. aeneus* in sites that contained rock outcrops and sites that did not. Burlap is commonly used to sample invertebrates (Duguay et al 2000). Thus, I suspected that burlap might provide artificial cover for salamanders using arboreal habitat, providing a simple means for sampling arboreal habitats. The goals of this chapter were to, 1) determine if burlap is an effective means of sampling *A. aeneus* populations, 2) compare burlap transect surveys to visual searches using area constrained surveys, and 3) compare diurnal surveys to nocturnal surveys.

Information gathered from this study will be valuable in evaluating the efficiency of using burlap in *A. aeneus* monitoring protocols and determining sampling conditions for optimal detection of *A. aeneus*. Land managers and researchers will benefit from this type of data because it may potentially provide a standardized method of surveying for *A. aeneus*.populations. Standardized methods increase the efficiency and repeatability of surveys (Fellers and Drost, 1994), which will allow for comparisons across researchers and over time. Additionally, this technique will help land managers determine if and when *A. aeneus* use arboreal habitat and enable them to collect information on the arboreality of *A. aeneus*.

METHODS

Study area/design

I conducted my research at Kanawha State Forest in Kanawha County, West Virginia. I constructed a circular plot (50 m diameter) at each of six study sites between March and May 2009 (Figure 4). I centered 3 of the sites on an emergent rock that was known to harbor *A. aeneus*, based on previous surveys. I centered the remaining 3 sites at randomly selected locations by taking a random bearing along trails. Sites that were devoid of emergent rocks will be referred to as “non emergent-rock sites” and those centered on emergent rocks, which will be referred to as “emergent-rock sites.” The emergent-rock sites contained sandstone conglomerate rocks. All sites were in mixed-deciduous forests on northwest sloping hillsides. Since *A. aeneus* have been documented to move ≥ 100 m, (Gordon 1952; Gordon 1961; Waldron and Humphries, 2005), I located my study plots at least 100 m apart, which decreased the probability that individuals moved between plots.

Each study site had eight 25 m transects radiating from a central point in directions of N, NE, E, SE, S, SW, W, NW (Figure 25). Each plot had a diameter of 50 m and encompassed an area of 1962.5 m^2 (0.1962 hectare). Approximately every 5 m along every other transect, I fastened 76.2 cm by 45.7 cm pieces of burlap fabric to trees by hemp rope 1.5 m from the ground (Thigpen, 2006). For small trees (DBH 4-8 cm), I cut the burlap pieces in half to achieve the same amount of coverage around the circumference of the tree with limited salamander obstruction. The burlap fabric I used is 100% natural and free of potentially harmful chemicals (Dupont Burlap, Dupont^{TM} Garden Products, Wilmington, Delaware). I attached burlap around trees (DBH ≥ 4 cm) so that it served as artificial arboreal cover, but did not impede salamander movement up the tree. Thus, I hung burlap pieces over rope that was tied around the trunk, allowing space between the tree and burlap (i.e., 5 cm) for unobstructed salamander movement. I identified every tree species located on transects and measured their DBH (APPENDIX I).

I placed a data logger (DS1923 micro- T temperature data logger, NexSens Technology, Inc., Alpha, Ohio) on 1 tree at each plot to record ambient temperature and relative humidity. To attain information about the microclimate the refuge provided, I also placed a data logger under burlap attached to the same tree to record air temperature and relative humidity (Figure 26). Data loggers recorded these values at a 2 hour 26 minute interval throughout the study period. I also placed a rain gauge at each site to collect rainfall between transect surveys.

Transect surveys

Between May and November 2009, I checked burlap for salamanders during diurnal and nocturnal surveys at least three times a month. I used this sampling protocol because daily surveys of artificial cover for Eastern Red-backed Salamanders (*Plethodon cinereus*) demonstrated higher counts underneath cover sampled weekly than underneath those sampled daily (Marsh and Goicochea, 2003). Prior to each survey, I noted the date, time at start of survey, and the number of people conducting the survey. I also recorded surface temperature, relative humidity, soil temperature, and current weather conditions.

I calculated person hours to quantify survey effort and adjusted this value when I found a salamander under burlap or on a tree by subtracting 10 minutes from the survey's person hours, based on the amount of time it took me to process a single salamander. Whenever I found a salamander, I recorded the time, weather condition, tree species and tree position on transect surveyed (i.e., tree number 3 on the NW transect). I also noted the orientation of the salamander on the tree (downward or upward facing) and salamander distance from the ground. I also recorded the actual distance between the tree and the nearest emergent rock. I measured captured salamanders for weight (g), sex, reproductive condition (i.e., swollen cloaca or eggs present), total length (TL; mm), and snout-vent length (SVL; mm). I used a digital camera to record the dorsal pattern of each captured salamander for individual recognition. (Waldron and Humphries, 2005). I released all salamanders at point of capture after processing.

Statistical Analyses

I determined percent survey success by attaining the percentage of times I observed *A. aeneus* under artificial cover. I used logistic regression to model the effects of, 1) the type of survey on detection of *A. aeneus* (diurnal vs. nocturnal and transect survey vs. area constrained survey from Chapter 2), and 2) the effects of environmental conditions on *A. aeneus* detection (soil temperature and weather, i.e., rain during the survey or no rain during the survey). I did not include non-emergent rock sites in this model because I did not find any *A. aeneus* at these sites. I performed the logistic regression using SAS (SAS Institute, Inc., Cary, North Carolina).

RESULTS

I performed 131 transect surveys throughout the survey period, spending a total of 153.8 person hours. I found 5 salamanders using artificial refuge (one was a Southern Two-lined Salamander [*Eurycea cirrigera*]) and 2 *A. aeneus* on non- burlap trees. Observations of salamanders using burlap occurred in August and September. Of my non-burlap captures, I found one in June and one in July (Figure 27). In September, I found 2 *A. aeneus* i using artificial cover on the same tree. All observations of salamanders on burlap/ non-burlap trees took place from mid- June to early September.

Out of 131 transect surveys, 4 *A. aeneus* individuals were found during 3 surveys, yielding a survey success of 2.3%. All salamanders found during nocturnal transect surveys were on non-burlap trees. I found salamanders under burlap only during diurnal surveys and when the burlap was wet (Figure 28). Figure 29 shows the salamander observations on trees by site. I did not find any *A. aeneus* using artificial cover at Site 1, despite encountering individuals of this species at this site in the beginning and end of the study period. I found a Southern Two-lined Salamander (*Eurycea cirrigera*) using artificial refuge on a *F. grandifola*. I did not encounter any salamanders at sites 4-6 on trees, both burlap and non-burlap, during my transect surveys. Four *A. aeneus* adults used burlap attached to *F. grandifola*. I found 1 *A. aeneus* juvenile under burlap attached to an Eastern Hemlock (*Tsuga canadensis*). I found 1 *A. aeneus* subadult on an *F. grandifola* that lacked burlap and 1 *A. aeneus* subadult on a *Q. alba* that lacked burlap.

Table 10 shows the morphometric data of salamanders and trees. The average tree DBH for *A. aeneus* observations was 49.8 cm. The average height of salamander observations on trees was 125.3 cm. I encountered *A. aeneus* a maximum linear distance of 14.2 m from a rock outcrop at Site 2. One *E. cirrigera* was on a tree 25 m from a rock outcrop at Site 1.

Table 11 lists environmental conditions recorded during surveys. No burlap captures occurred before 1359 hours during diurnal surveys. All burlap captures occurred during periods of rain when the burlap was saturated. I did not find *A. aeneus* on non-burlap trees prior to 2151 hours and during rainy weather conditions. Table 11 also includes conditions under burlap at times of salamander observations. August had the highest average precipitation (5.9 cm) that accumulated between transect surveys (average 15.8 days elapsed) (Figure 30) and September had the lowest average precipitation (0.94 cm) that accumulated between transect surveys (average 7.86 days elapsed).

Nocturnal surveys were more effective than diurnal surveys ($\chi^2 = 5.644$, df = 1, $p < 0.001$). Detection was positively associated with nocturnal surveys ($\beta = 0.7027 \pm 0.2958$; $\chi^2 = 5.6445$; df = 1; $p < 0.05$), which were 4 times more likely to detect *A. aeneus* (point estimate = 4.007, 95% CI = 1.279-12.997). Detection was positively associated with rock surveys ($\beta = 2.4775 \pm 0.3835$, $\chi^2 = 41.7332$, df = 1; $p < 0.0001$) and negatively associated with both burlap ($\beta = -1.2387 \pm 0.5378$, $\chi^2 = 5.3047$, df = 1; $p < 0.05$) and non-burlap surveys ($\beta = -1.2387 \pm 0.5378$, $\chi^2 = 5.3047$, df = 1; $p < 0.05$). Rock surveys were 41 times more likely to detect *A. aeneus* than burlap surveys (point estimate = 41.113, 95% CI = 9.2-183.723). Burlap and non-burlap were equally effective at detecting salamanders (point estimate = 1.00, 95% CI = 0.140-7.169) surveys. There was no significant effect of weather ($\chi^2 = 0.6076$, df = 1, $p > 0.05$) and soil temperature ($\chi^2 = 0.3910$, df = 1, $p > 0.05$).

DISCUSSION

Artificial Arboreal Cover Use and Microclimate

Oversampling cover objects dries out microhabitats and residing salamanders to abandon these cover items (Marsh and Goicochea, 2003). Marsh and Goicochea (2003) found that sampling cover boards daily reduced salamander counts under cover items. However, they found no difference in salamander counts when comparing cover boards sampled weekly and every 3 weeks. To avoid oversampling, I conducted transect surveys at my sites, at most, once a week by sampling marked non-burlap trees and burlap. After 131 surveys, I found 4 *A. aeneus* using artificial arboreal cover, I do not believe that such a low count was attributed to oversampling.

Typically, amphibians can be found under cover objects during wet periods of the year (Fellers and Drost, 1994). Thigpen (2006) found 11 *A. aeneus* subadults, 16 Southern Appalachian Slimy Salamanders (*Plethodon chlorobryonis*), 1 Ocoee Salamander (*Desmognathus ocoee*), and 3 Southern Gray-cheeked Salamanders (*Plethodon metcalfi*). I found 1 Southern Two-lined Salamander (*Eurycea cirrigera*) using artificial cover on a rainy day, a salamander typically associated with streams and moist forests (Petranka, 1998). I captured *A. aeneus* under burlap when the substrate was saturated. The burlap did not retain moisture for more than a few days which could be why I encountered less individuals using this refuge due to lack of a suitable microclimate. Thigpen (2006) found the same dryness of burlap and suggested another substrate such as bark be attached to trees to provide better microclimates for salamanders.

Additionally, data loggers under burlap reveal how close the temperature and relative conditions are to ambient conditions. Houze and Chandler (2002) found that temperature under cover objects was important to salamanders. Data loggers in their study demonstrated that cover boards were poor at maintaining constant temperatures, especially in late summer, and the researchers implied that thicker boards or alternative materials might create microclimates similar to natural cover. Perhaps thicker layers of burlap would provide a more suitable microclimate for salamander refugia.

Tree Selection and Distance from Emergent Rocks

While this study demonstrated that *A. aeneus* detection did not increase with the use of artificial cover, it provided information about the arboreal habits of *A. aeneus* in West Virginia. *Aneides aeneus* appeared to prefer large *F. grandifola*; and was found on this tree species a distance away from emergent rocks, when smaller American Beech trees were closer to the associated emergent rocks. Waldron and Humphries (2005) found *A. aeneus* as far as 42 m from a rock outcrop, but Thigpen (2006) did not find *A. aeneus* on trees farther than 10 m from associated rock outcrop.

I observed *A. aeneus* on trees as high as 129 cm, largely due to location of artificial cover. I encountered an *A. aeneus* under artificial cover 14.2 m away from a rock outcrop on a large *F. grandifola* (DBH = 45 cm). I also found an *A. aeneus* on a *F. grandifola* (DBH = 76 cm) (non-burlap tree) that was12.1 m from a rock outcrop. Waldron and Humphries (2005) observed an *A. aeneus* individual 21 m up a tree, so the height of burlap on the trees I surveyed may not give justice to the height that *A. aeneus* can be detected. Perhaps using burlap at a higher location on the tree, such as 3-4 m from the ground will provide more date on the climbing ability of *A. aeneus*.

I also found 2 *A. aeneus* under burlap on the same *F. grandifola* that had a 60 cm DBH. This tree was 6 m from the associated rock outcrop, so these individuals did not travel far to arboreal habitat. Waldron and Humphries (2005) found *A.aeneus* using arboreal habitat in large, older beeches and inferred that such large, lichen-covered trees with numerous holes provided extensive habitat for *A. aeneus*. They made 58 *A. aeneus* observations on a single *F. grandifola* (that had a 75 cm DBH) and was 2 m from a rock outcrop.

Although it seems that *A. aeneus* prefer large hardwoods with many holes, some trees documented to be used by *A. aeneus* may provide cover through a series of bark characteristics, such as flaking (Waldron and Humphries, 2005). I found *A. aeneus* on *Q. alba* and *T. Canadensis*, which are tree species that share these traits of rough bark that may provide refuge for *A. aeneus*.

Seasonal Activity

The timing of salamanders observed on trees and under burlap during my study supported other findings in which *A. aeneus* exhibited seasonal arboreal activity. My results indicated a period of *A. aeneus* seasonal arboreal activity in West Virginia,that was similar to aSouth Carolina population (Waldron and Humphries, 2005). In South Carolina, *A. aeneus* moved from rock outcrops to trees in late March and early April, and returned to rock outcrops as colder weather approached in late October early November (Waldron and Humphries, 2005).

I first encountered evidence of arboreal activity on a non-burlap tree during a transect survey in June and found another individual on a non-burlap tree the following month. My observations of 2 *A. aeneus* under burlap on trees in August, during the same transect survey, when no individuals were found on rocks (data from Chapter 2), with the exception of brooding females, demonstrate movement to trees. I found 2 more *A. aeneus* under burlap on the same tree in September and no more for the duration of the study period. The arboreal activity period I observed at Kanawha State Forest began in June and lasted until September.

Time of Arboreal Activity

I found all 4 *A. aeneus* under artificial cover during diurnal surveys. The times of capture ranged from 1359 to 1645 hours. Thigpen (2006) was unable to capture salamanders under burlap prior to 1600 hours in a study conducted in North Carolina. I did not observe any *A. aeneus* on trees, not using artificial cover, prior to 2151 hours and after 0159 hours. This supports evidence that *A. aeneus* is most active at night and forage (Green and Pauley, 1987) on the trees. I found a variety of insects, mostly Coleopterans (beetles) and Hymenopterans (ants), beneath the burlap, typically during nocturnal surveys. Such insects are primary prey items for *A. aeneus* in West Virginia (Lee and Norden, 1973). Jaeger (1978) found that salamanders that climb plants at night consume a significantly larger volume of prey than others that forage on the forest floor at night**.** *A. aeneus’* ability to climb up trunks allows them to exploit food from other salamanders that have a weaker ability to climb.

Evaluation of Effectiveness of Transect Surveys Using Artificial Arboreal Cover

One disadvantage of using artificial cover to sample species is that effectiveness may vary among species (Fellers and Drost, 1994). After 131 surveys in the study area, I found 6 *A. aeneus* during transect surveys, with 4 using artificial cover. Although I observed more arboreal activity during the transect surveys, data analyses revealed that rock surveys from area constrained surveys were more effective at detecting Aa than transect surveys, regardless of whether burlap was present. I found 37 individuals during area constrained surveys as compared to 6 that were encountered during transect surveys.

The principle advantages of using cover objects are that salamanders are easier to find beneath them, and that search efforts can be restricted to these objects (Marsh and Goicochea, 2003). However, typical area constrained search efforts for *A. aeneus* that focus on rock outcrops (Waldron and Humphries, 2005) may be beneficial for the detection of *A. aeneus* and transect surveys using artificial cover may be used to attain more information on arboreal habits of this species. My results revealed that nocturnal surveys were better at *A. aeneus* detection than diurnal surveys. This finding was not surprising since *A. aeneus* is most active at night and emerges from crevices and climb on the rock outcrop in search of food (Green and Pauley, 1987), especially after 2200 hours (T.K. Pauley, pers. communication). I encountered *A. aeneus* during the day in crevices and under burlap, but these individuals were seeking refuge, and not immediately visible, hence why detection at night is better due to *A. aeneus* activity and increased visibility.

The lack of effect of weather and soil temperature on *A. aeneus* detection was surprising since amphibian activity is largely dependent on environmental conditions (Keen, 1984). Kleeberger and Werner (1982) found that daily movement of salamanders came after periods of rainfall. Keen (1984) found that the duration of activity in *Desmognathus fuscus*, a plethodontid species, was directly related to environmental and substrate moisture level. Gordon (1952) and Netting and Richmond

(1932) documented the occurrence of *A. aeneus* foraging on rock outcrops, particularly on rainy nights. I encountered *A. aeneus* foraging on emergent rocks regardless of rain, even when moss on an emergent rock was dry. Since *A. aeneus* are desiccation tolerant (Gordon, 1952), their activity may not be as limited by precipitation as other plethodontid species, allowing this species to be more active under various conditions and therefore detectable by researchers.

Based on my observations nocturnal rock surveys are the most successful sampling method to monitor *A. aeneus* populations since I found more *A. aeneus* using this technique. This survey would be effective at determining the presence of *A. aeneus* as well as monitoring populations over time. However, if assessing or monitoring the arboreality of *A. aeneus* and, more specifically, determining what tree species they are using for arboreal habitat, attaching burlap bands to trees is useful. When using this method, I recommend sampling burlap during the day (1400–1800 h), under rainy conditions, and when the burlap is wet, since these are the conditions during which I encountered *A. aeneus* under burlap.

FINAL THOUGHTS: CONSERVATION INITIATIVES

Since timbering in areas adjacent to rock outcrops desiccates crevices used for foraging and nesting and can lead to the extinction of local populations, researchers have recommended the use of forest buffers around rock outcrops (Petranka, 1998) and Waldron and Humphries 2005)). The implementation of this forest management strategy is vital for *A. aeneus* populations at Kanawha State Forest. Although I observed a distance moved of 14.8 m from the point of capture, other researchers observed distances traveled by *A. aeneus* of close to 100 m, so a buffer of 100 m would provide optimal continuous forest surrounding emergent rocks that harbor *A. aeneus.*

While this study demonstrated that *A. aeneus* detection is not necessarily increased using artificial cover arrays, it provided information about the arboreal habits of *A. aeneus* in West Virginia. The individuals that I tracked in arboreal habitat were encountered on *B*. *alleghaniensis*, both growing on top of the associated rock outcrop. *Aneides aeneus* also appeared to prefer large *F. grandifola*; individuals were found away from emergent rocks on this tree species, when smaller American Beech trees were in between the associated emergent rock and tree that I found *A. aeneus* on. I encountered an *A. aeneus* using cover 14.2 m away from a rock outcrop on a large *F. grandifola* with a DBH of 45 cm. I also found an *A. aeneus* on an *F. grandifola* with a DBH of 76 cm (non-burlap tree) 12.1 m from a rock outcrop. These tree species and characteristics should also be taken into consideration when making forest management decisions within the range of this distinctive salamander species (Waldron and Humphries, 2005).

Based on my observations, nocturnal rock surveys are the most successful sampling method to monitor *A. aeneus* populations since I found more *A. aeneus* using this technique. This survey would be effective at determining the presence of *A. aeneus* as well as biomonitoring populations over time. Attaching burlap bands to trees is useful, if assessing or monitoring the arboreality of *A. aeneus* and, more specifically, determining what tree species they are using for arboreal habitat. When using this method, I recommend sampling burlap during the day, under rainy conditions, and when the burlap is wet, since these are the conditions during which I encountered *A. aeneus* under burlap.

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Table 1. Table 1. Tree species frequency, density (stems ha^{-1}), basal area (m^{2} ha^{-1}), relative (rel.) frequency, relative (rel.) density (stems ha^{-1}), relative (rel.) basal area (m^{2} ha^{-1}), and importance value at each site. I calculated relative values of species frequency by dividing the species frequency by the total frequency of all species combined and expressing the result as a percentage. I calculated relative species dominance (basal area) (m^{2} ha^{-1}) and relative species density (stems ha^{-1}) the same way.

Site #	Species Name	Species Frequency	Species Density	Species Basal Area	Rel. Frequency	Rel. Density	Rel. Basal Area	Imp. Value
1	*F. grandifolia*	1	1833.33	0.06	22.64	41.04	10.94	74.63
	Q. alba	0.58	333.33	0.2	13.21	7.46	36.17	56.84
	A. saccharum	0.83	800	0.04	18.87	17.91	7.49	44.27
	L. tulipifera	0.42	366.67	0.12	9.43	8.21	20.64	38.28
	Q. rubra	0.42	200	0.09	9.43	4.48	15.73	29.64
	T. canadensis	0.42	466.67	0.02	9.43	10.45	4.29	24.17
	A. rubrum	0.25	266.67	0.01	5.66	5.97	0.94	12.57
	J. nigra	0.25	100	0.02	5.66	2.24	3.02	10.92
	C. gabra	0.17	66.67	0	3.77	1.49	0.05	5.31
	T. americana	0.08	33.33	0	1.89	0.75	0.73	3.36
2	*T. canadensis*	0.92	2566.67	0.36	28.94	55.4	37.14	121.48
	Q. alba	0.67	500	0.31	21.05	10.79	31.88	63.72
	F. grandifolia	0.67	1033.33	0.16	21.05	22.3	16.08	59.43
	L. tulipifera	0.33	233.33	0.08	10.53	5.04	7.9	23.46
	A. rubrum	0.17	100	0.02	5.26	2.16	2.19	9.61
	Q. rubra	0.08	33.33	0.04	2.63	0.72	3.8	7.15
	A. saccharum	0.17	66.67	0	5.26	1.44	0.18	6.88
	C. gabra	0.08	66.67	0	2.63	1.44	0.14	4.21
	J. nigra	0.08	33.33	0.01	2.63	0.72	0.69	4.04
3	*F. grandifolia*	0.92	1266.67	104.18	31.39	35.19	35.64	102.22
	A. saccharum	0.92	1600	26.22	31.39	44.44	8.97	84.81
	Q. alba	0.58	266.67	136.66	19.98	7.41	46.75	74.14
	L. tulipifera	0.17	133.33	21.71	5.71	3.7	7.43	16.84
	T. canadensis	0.08	200	2.42	2.85	5.56	0.83	9.24
	C. gabra	0.17	100	0.53	5.71	2.78	0.18	8.67
	Q. rubra	0.08	33.33	0.59	2.85	0.93	0.2	3.98
4	*Q. alba*	0.67	366.67	163.89	18.6	12.36	77.72	108.69
	T. canadensis	1	1333.33	27.6	27.91	44.94	13.09	85.94
	F. grandifolia	0.75	700	19.42	20.93	23.6	9.21	53.73
	L. tulipifera	0.42	200	14.4	11.63	6.74	6.83	25.2
	Q. rubra	0.17	66.67	3.4	4.65	2.25	1.61	8.51

Table 1. Table 1. Tree species frequency, density (stems ha^{-1}), basal area (m^{2} ha^{-1}), relative (rel.) frequency, relative (rel.) density (stems ha^{-1}), relative (rel.) basal area (m^{2} ha^{-1}), and importance (imp.) value at each site. I calculated relative values of species frequency by dividing the species frequency by the total frequency of all species combined and expressing the result as a percentage. I calculated relative species dominance (basal area) (m^{2} ha^{-1}) and relative species density (stems ha^{-1}) the same way.

Site #	**Species Name**	**Species Frequency**	**Species Density**	**Species Basal Area**	**Rel. Frequency**	**Rel. Density**	**Rel. Basal Area**	**Imp. Value**
4	*A. saccharum*	0.17	100	0.5	4.65	3.37	0.24	8.26
	T. americana	0.17	66.67	2.23	4.65	2.25	1.06	7.95
	C. gabra	0.08	66.67	0	2.33	2.25	0	4.57
	A. rubrum	0.08	33.33	1.38	2.33	1.12	0.66	4.11
	J. nigra	0.08	33.33	0.26	2.33	1.12	0.12	3.57
5	*T. americana*	0.83	533.33	202.78	25	14.04	68.12	107.16
	A. saccharum	0.92	1766.67	30.23	27.5	46.49	10.16	84.15
	F. grandifolia	1	1100	16.34	30	28.95	5.49	64.44
	C. gabra	0.17	233.33	0.69	5	6.14	0.23	11.37
	Q. alba	0.08	33.33	16.76	2.5	0.88	5.63	9.01
	L tulipifera	0.08	33.33	5.3	2.5	0.88	1.78	5.16
	P. serotina	0.08	33.33	2.78	2.5	0.88	0.93	4.31
	J. nigra	0.08	33.33	2.78	2.5	0.88	0.93	4.31
	B. alleghaniensis	0.08	33.33	0.59	2.5	0.88	0.2	3.58
6	*T. americana*	0.92	1266.67	145.91	33.33	26.39	45.33	105.05
	A. saccharum	0.92	2700	38.64	33.33	56.25	12	101.59
	F. grandifolia	0.42	566.67	14.95	15.15	11.81	4.64	31.6
	Q. rubra	0.25	100	19.89	9.09	2.08	6.18	17.35
	L. tulipifera	0.17	133.33	0	6.06	2.78	0	8.84
	J. nigra	0.08	33.33	5.3	3.03	0.69	1.65	5.37

Table 2. Morphometric data, based on 1st capture for all *A. aeneus* captured. A "U" indicates that the sex of the individual was unknown. "M" refers to males. "F" refers to female. "NR" refers to non-reproductive.

ID #	Species	Site	Date Captured	SVL mm	TL mm	Mass (g)	Size Class	Sex	Reproductive Condition
1	*A. aeneus*	2	12-May	26.2	63.3	0.40	Juvenile	U	NR
2	*A. aeneus*	2	12-May	37.7	88.7	1.30	Subadult	U	NR
3	*A. aeneus*	2	24-May	15.9	22.3	0.10	Juvenile	U	NR
4	*A. aeneus*	2	24-May	26.6	38.1	0.50	Juvenile	U	NR
5	*A. aeneus*	2	5-Jun	25.3	38.0	0.45	Juvenile	U	NR
6	*A. aeneus*	2	5-Jun	33.0	74.1	1.10	Subadult	U	NR
7	*A. aeneus*	2	23-Jun	19.8	34.8	0.25	Juvenile	U	NR
8	*A. aeneus*	2	23-Jun	21.3	38.5	0.28	Juvenile	U	NR
9	*A. aeneus*	2	23-Jun	36.7	44.0	0.75	Subadult	U	NR
10	*A. aeneus*	2	23-Jun	53.8	112.0	3.50	Adult	M	NR
11	*A. aeneus*	2	23-Jun	46.8	92.4	2.10	Adult	F	NR
12	*A. aeneus*	2	23-Jun	58.6	105.4	2.10	Adult	F	NR
13	*A. aeneus*	2	24-Jun	45.3	74.1	1.45	Adult	F	NR
14	*A. aeneus*	2	28-Jun	38.8	70.1	1.40	Subadult	U	NR
15	*A. aeneus*	2	28-Jun	22.1	45.9	0.25	Juvenile	U	NR
16	*A. aeneus*	2	28-Jun	56.2	112.8	3.00	Adult	F	NR
17	*A. aeneus*	2	2-Jul	42.6	93.6	1.20	Subadult	U	NR
18	*A. aeneus*	2	8-Jul	35.6	55.2	0.80	Subadult	U	NR
19	*A. aeneus*	2	5-Aug	23.3	52.6	0.7	Juvenile	U	NR
20	*A. aeneus*	2	5-Aug	44.7	87.5	1.65	Adult	F	NR
21	*A. aeneus*	3	7-Sep	40.8	82.5	2	Subadult	U	NR
22	*A. aeneus*	3	7-Sep	44.5	81.5	1.9	Adult	F	NR
23	*A. aeneus*	1	23-Sep	45.0	91.0	2.15	Adult	F	NR
24	*A. aeneus*	2	23-Sep	46.7	84.6	2.25	Adult	M	NR
25	*A. aeneus*	2	23-Sep	43.0	77.7	1.70	Subadult	U	NR
26	*A. aeneus*	2	23-Sep	46.6	92.1	3.30	Adult	F	NR
27	*A. aeneus*	2	23-Sep	37.2	79.0	1.70	Subadult	U	NR
28	*A. aeneus*	2	4-Oct	38.4	70.6	1.00	Subadult	U	NR
29	*A. aeneus*	2	8-Oct	52.2	105.3	3.50	Adult	F	NR
30	*A. aeneus*	2	8-Oct	31.2	63.5	0.50	Subadult	U	NR
31	*A. aeneus*	2	8-Oct	52.8	106.4	2.90	Adult	F	NR
32	*A. aeneus*	2	8-Oct	59.5	123.4	3.40	Adult	F	NR
33	*A. aeneus*	2	15-Oct	59.1	128.1	4.60	Adult	M	NR
34	*A. aeneus*	2	15-Oct	49.0	103.7	4.60	Adult	M	NR
35	*A. aeneus*	1	30-Oct	53.9	120.7	3.50	Adult	M	NR
36	*A. aeneus*	2	30-Oct	45.0	101.0	2.20	Adult	F	NR
37	*A. aeneus*	2	30-Oct	28.2	51.0	0.85	Juvenile	U	NR

Table 3. Morphometric data for all *P. kentucki* captured A “U” indicates that the sex of the individual was unknown. “M” refers to males. “F” refers to female. “NR” refers to non-reproductive.

ID #	Species	Site	Date Captured	SVL (mm)	TL (mm)	Mass (g)	Size Class	Sex	Reproductive Condition
1	*P. kentucki*	2	24-May	64.80	123.30	6.10	Adult	M	R
2	*P. kentucki*	2	24-May	47.80	116.80	1.00	Juvenile	U	NR
3	*P. kentucki*	2	24-May	62.00	130.00	5.40	Adult	F	NR
4	*P. kentucki*	1	25-May	54.90	120.00	5.00	Adult	F	NR
5	*P. kentucki*	1	25-May	44.00	96.70	6.30	Adult	F	NR
6	*P. kentucki*	1	25-May	32.80	99.00	2.00	Juvenile	U	NR
7	*P. kentucki*	1	26-May	48.40	97.40	6.00	Adult	M	R
8	*P. kentucki*	1	26-May	43.00	95.00	5.50	Adult	M	NR
9	*P. kentucki*	5	26-May	57.00	113.00	7.50	Adult	F	NR
10	*P. kentucki*	5	26-May	56.00	117.00	9.40	Adult	F	NR
11	*P. kentucki*	2	31-May	69.50	140.30	10.00	Adult	M	R
12	*P. kentucki*	4	5-Jun	55.00	130.00	9.50	Adult	F	NR
13	*P. kentucki*	4	5-Jun	48.40	97.40	6.00	Adult	F	NR
14	*P. kentucki*	4	5-Jun	43.00	95.00	5.50	Adult	F	NR
15	*P. kentucki*	4	5-Jun	57.00	113.00	8.50	Adult	F	NR
16	*P. kentucki*	4	5-Jun	58.00	113.00	8.20	Adult	M	R
17	*P. kentucki*	4	6-Jun	65.90	146.39	7.45	Adult	F	NR
18	*P. kentucki*	2	7-Jun	67.89	155.95	5.65	Adult	F	NR
19	*P. kentucki*	1	4-Oct	52.10	111.30	5.20	Adult	F	NR
20	*P. kentucki*	1	4-Oct	62.10	121.70	6.50	Adult	M	NR
21	*P. kentucki*	2	4-Oct	46.70	94.90	5.50	Adult	F	NR

Table 4. Movement data for all *A. aeneus* tracked using pigment powder. “Season” corresponds to salamander activity, not calendar year. For “Season”: “Sp”= spring, “Su”= summer, and “Fa”= fall. For “Sex”: “M” = males, “F” = females and a “U” indicates that the sex of the individual was unknown. For “Size Class”: an “I” indicates all sexually immature individuals (both juveniles and subadults), an “M” indicates sexually mature individuals. “Habitat 1” refers to habitat of capture. “Habitat 2” refers to habitat found after I tracked movement. “R” refers to open rockface, “C” refers to within crevice of an emergent rock, “T” refers to tree, and “G” refers to ground.

ID #	Site	Month	Season	Time	SVL (mm)	Sex	Size Class	Distance (cm)	Habitat1	Habitat2
1	2	May	Sp	21.83	26.20	U	I	470	R	C
2	2	May	Sp	21.83	37.70	U	I	0	.	.
3	2	May	Sp	22.42	15.90	U	I	88.5	R	C
4	2	May	Sp	22.42	26.60	U	I	573	R	C
5	2	Jun	Sp	23.95	25.30	U	I	99	R	C
6	2	Jun	Sp	23.90	33.00	U	I	116.9	R	R
7	2	Jun	Sp	21.13	19.80	U	I	297.6	R	C
8	2	Jul	Su	21.88	21.30	U	I	284.1	R	C
8	2	Jul	Su	26.38	21.30	U	I	157	R	C
8	2	Jul	Su	23.90	21.30	U	I	77.8	C	R
8	2	Jun	Sp	23.43	21.30	U	I	72.75	R	C
8	2	Jun	Sp	22.42	21.30	U	I	136.8	C	R
9	2	Jun	Sp	22.78	36.70	U	I	97.43	R	R
10	2	Jun	Sp	21.82	53.80	M	M	339.5	C	C
11	2	Jun	Sp	23.18	46.80	F	M	298.3	R	C
12	2	Jun	Sp	23.05	58.60	F	M	401.8	C	C
13	2	Jun	Sp	22.07	45.30	F	M	237.8	C	C
14	2	Jun	Sp	23.17	38.80	U	I	263.5	R	C
15	2	Jun	Sp	23.05	22.10	U	I	154.7	R	C
16	2	Jun	Sp	23.02	56.20	F	M	311.7	R	C
17	2	Jul	Su	23.75	42.60	U	I	0	.	.
18	2	Jul	Su	26.70	35.60	U	I	301.8	R	C
19	2	Aug	Su	17.98	23.30	U	I	130	T	T
20	2	Aug	Su	18.08	44.70	F	M	148	T	R
21	3	Oct	Fa	22.65	40.80	U	I	25.7	C	R
21	3	Sep	Fa	21.48	40.80	U	I	189	T	T
22	3	Sep	Fa	21.75	44.50	F	M	580	T	G
23	1	Oct	Fa	23.55	45.00	F	M	90.1	C	R
23	1	Oct	Fa	21.55	45.00	F	M	187.2	C	R
23	1	Sep	Fa	23.68	45.00	F	M	170.6	C	R
24	2	Sep	Fa	23.18	46.70	M	M	314.1	R	C
25	2	Sep	Fa	23.32	43.00	U	I	1476	R	T
26	2	Sep	Fa	23.25	46.60	F	M	290	C	R
27	2	Sep	Fa	23.25	37.20	U	I	274.7	C	R
28	2	Oct	Fa	23.77	38.40	U	I	492	C	C
29	2	Oct	Fa	23.12	52.20	F	M	0	.	.

Table 4. Movement data for all *A. aeneus* tracked using pigment powder. “Season” corresponds to salamander activity, not calendar year. For “Season”: “Sp”= spring, “Su”= summer, and “Fa”= fall. For “Sex”: “M” = males, “F” = females and a “U” indicates that the sex of the individual was unknown. For “Size Class”: an “I” indicates all sexually immature individuals (both juveniles and subadults), an “M” indicates sexually mature individuals. “Habitat 1” refers to habitat of capture. “Habitat 2” refers to habitat found after I tracked movement. “R” refers to open rockface, “C” refers to within crevice of an emergent rock, “T” refers to tree, and “G” refers to ground.

ID #	Site	Month	Season	Time	SVL (mm)	Sex	Size Class	Distance (cm)	Habitat1	Habitat2
30	2	Oct	Fa	23.48	31.20	U	I	231.2	R	R
31	2	Oct	Fa	23.75	52.80	F	M	381	C	C
31	2	Oct	Fa	22.27	52.80	M	M	730.1	R	C
32	2	Oct	Fa	23.80	59.50	F	M	93.5	C	R
33	2	Oct	Fa	23.10	59.1	M	M	775.1	R	R
34	2	Oct	Fa	22.80	49	M	M	408	T	T
35	1	Oct	Fa	22.28	53.9	M	M	57	C	R
36	2	Oct	Fa	22.02	45	F	M	76	R	R
37	2	Oct	Fa	21.78	28.2	U	I	10	C	R

Table 5. Movement pattern data for all *P. kentucki* tracked. “Season” corresponds to salamander activity, not calendar year. For “Season”: “Sp”= spring, “Su”= summer, and “Fa”= fall. For “Sex”: “M” = males, “F” = females and a “U” indicates that the sex of the individual was unknown. For “Size Class”: an “I” indicates all sexually immature individuals (both juveniles and subadults), an “M” indicates sexually mature individuals. “Habitat 1” refers to habitat of capture. “Habitat 2” refers to habitat found after I tracked movement. “R” refers to open rockface, “C” refers to cover (i.e., log, rock, etc.), “T” refers to tree, and “G” refers to ground.

ID #	**Site**	**Month**	**Season**	**Time**	**SVL (mm)**	**Sex**	**Age Class**	**Distance (cm)**	**Habitat1**	**Habitat2**
1	2	May	Sp	21.5	64.8	M	M	136.4	G	G
2	2	May	Sp	21.8	47.8	U	I	77.9	G	G
3	2	May	Sp	21.83	62	F	M	90	G	C
4	1	May	Sp	19.22	54.9	F	M	123	G	G
5	1	May	Sp	19.3	44	F	M	98.3	C	G
6	1	May	Sp	19.58	32.8	U	I	145	C	G
7	1	May	Sp	19.17	48.4	M	M	202	G	G
8	1	May	Sp	19.33	43	M	M	221	G	G
9	5	May	Sp	20	57	F	M	95	G	C
10	5	May	Sp	20.25	56	F	M	0	.	.
11	2	May	Sp	21.43	69.5	M	M	261.4	C	G
12	4	Jun	Sp	22.25	55	F	M	96	G	G
13	4	Jun	Sp	22.25	48.4	F	M	192.4	G	
14	4	Jun	Sp	22.25	43	F	M	143.5	G	G
15	4	Jun	Sp	22.25	57	F	M	119.75	G	C
16	4	Jun	Sp	21.97	58	M	M	425.2	C	T
17	4	Jun	Sp	22.97	65.9	F	M	116	G	C
18	2	Jun	Sp	23.97	67.89	F	M	538	G	C
19	1	Oct	Fa	20.08	52.1	F	M	223	G	C
20	1	Oct	Fa	20.45	62.1	M	M	430.5	G	C
21	2	Oct	Fa	20.73	46.7	F	M	0	.	.

Table 6. Descriptive statistics of *A. aeneus* (Aa) and *P. kentucki* (Pk): sex, species, and transformed movement distance.

Species	Sex	N	Mean Distance (cm)	SD
Aa	combined	20	15.83	6.8
	F	14	14.13	60.2
	M	6	19.79	7.39
Pk	combined	19	12.32	5.91
	F	13	10.4	5.90
	M	6	16.38	3.64
Combined	F	27	12.35	6.14
Combined	M	12	18.09	5.83

Table 7. Two-way ANOVA statistics assessing effects of species, sex, and species*sex. Model was significant (F = 3.80, df = 3, *p* = 0.0186).

Source	**DF**	**SS (Type III)**	**Mean Square**	**F**	***p***
Species	1	104.34	104.64	2.98	0.0930
Sex	1	279.61	279.61	7.97	0.0070
Species*Sex	1	0.16	0.16	0.00	0.9464

Table 8. Descriptive data for untransformed distance movement by season and habitat.

Effects	N	Mean (cm)	SD
Season			
Spring	17	232.90	156.77
Summer	7	156.96	107.12
Fall	21	326.25	346.80
Habitat1			
Tree	5	291	196.20
Crevice	18	181.42	152.89
Rock	22	326.76	329.58

Table 9. Results of two- way ANOVA testing the effects of season, habitat1, and their interaction on *A. aeneus* movement. The model was not significant (f = 3.11, df = 13, p= 0.0062.

Effect	**DF**	**Type III SS**	**Mean Square**	**F**	***p***
Season	2	198.72	99.36	1.82	0.1764
Habitat1	2	298.53	149.26	2.73	0.0782
Season*Habitat1	3	108.62	36.21	0.66	0.5802

Table 10. Morphometric data of species found on trees during burlap surveys. “A” refers to adult. “S” refers to subadult. “J” refers to Juvenile. “U” refers to unknown sex. “NB” refers to non-burlap tree. “B” refers to burlap tree.

Date	**Site**	**Tree**	**Tree Species**	**DBH (cm)**	**Distance From Outcrop (m)**	**Species**	**Height on Tree (cm)**	**SVL (mm)**	**TL (mm)**	**Mass (g)**	**Size Class**	**Sex**
7-Sep	1	B	American Beech	75	26.0	*E. cirrigera*	105				A	U
18-Jun	2	NB	White Oak	40	7.9	*A. aeneus*	103	29.8	69.6	0.99	S	U
5-Aug	2	B	Eastern Hemlock	18	4.7	*A. aeneus*	131	23.3	52.6	0.70	J	U
5-Aug	2	B	American Beech	45	14.2	*A. aeneus*	136	44.7	87.5	1.65	A	F
9-Jul	3	NB	American Beech	76	12.1	*A. aeneus*	149	39.9	87.0	1.10	S	U
7-Sep	3	B	American Beech	60	6.0	*A. aeneus*	122	40.8	82.5	2.00	S	U
7-Sep	3	B	American Beech	60	6.0	*A. aeneus*	131	44.5	81.5	1.90	A	F

Table 11. Environmental data of conditions when I found salamanders on trees during burlap surveys. “RH” refers to Relative Humidity “NB” refers to non-burlap tree. “B” refers to tree with attached burlap.* Indicates Same tree that was surveyed.

Date	Site	Time	Species	Tree	Conditions	Ambient Temp (ºC)	Ambient RH (%)	Temp Under Burlap (ºC)	RH Under Burlap (%)
7-Sep	1	17:54	*E. cirrigera*	B	Rain	20	97	20	98
18-Jun	2	1:25	*A. aeneus*	NB	No Rain	21.5	81	22.5	77
5-Aug	2	13:59	*A. aeneus*	B	Rain	19	102	19	100
5-Aug	2	14:20	*A. aeneus*	B	Rain	19	102	19	100
9-Jul	3	21:51	*A. aeneus*	NB	No Rain	21.5	81	22.5	77
7-Sep*	3	16:44	*A. aeneus*	B	Rain	20.5	97	21	96
7-Sep*	3	16:45	*A. aeneus*	B	Rain	20.5	97	21	96

Figure 1. Adult Green Salamander (*A. aeneus*) on emergent rock. Photo taken May 2009 by Sarah E. Miloski.

Figure 2. Distribution of *A. aeneus* in the United States (Petranka 1998).

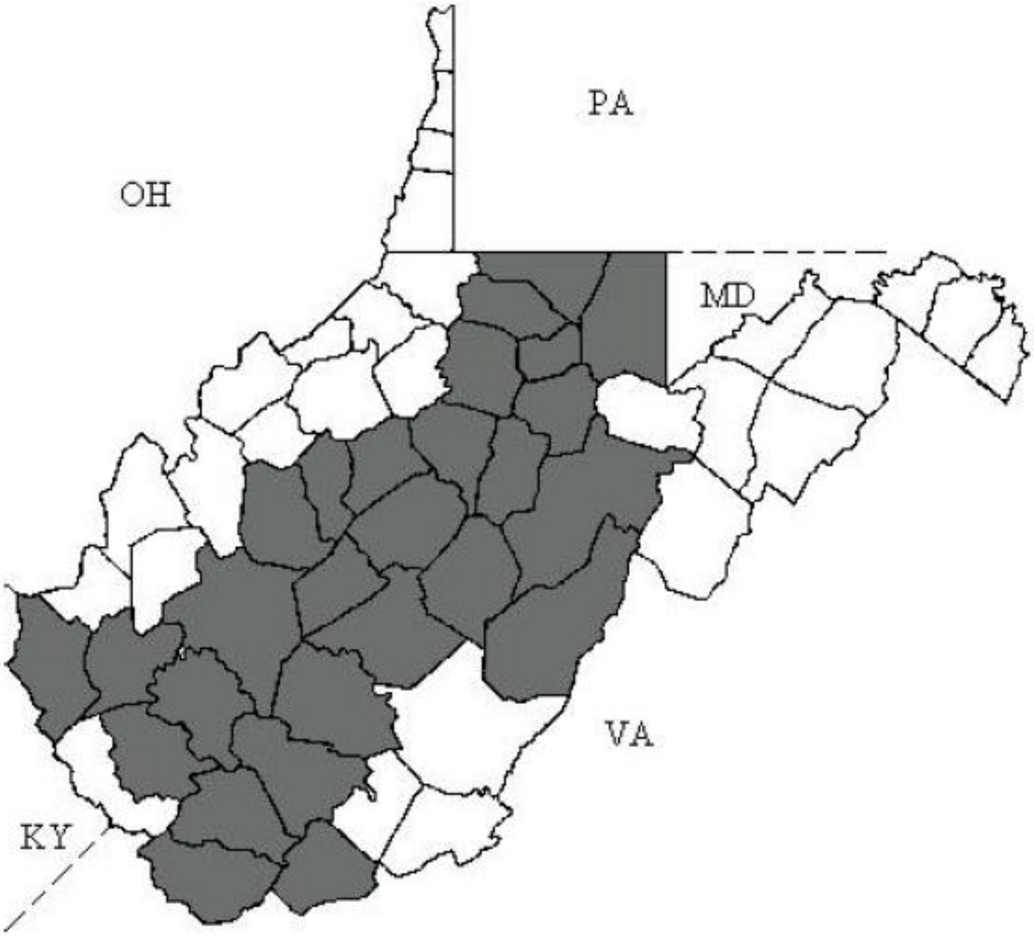

Figure 3. Range of *A. aeneus* in West Virginia (Green and Pauley 1987).

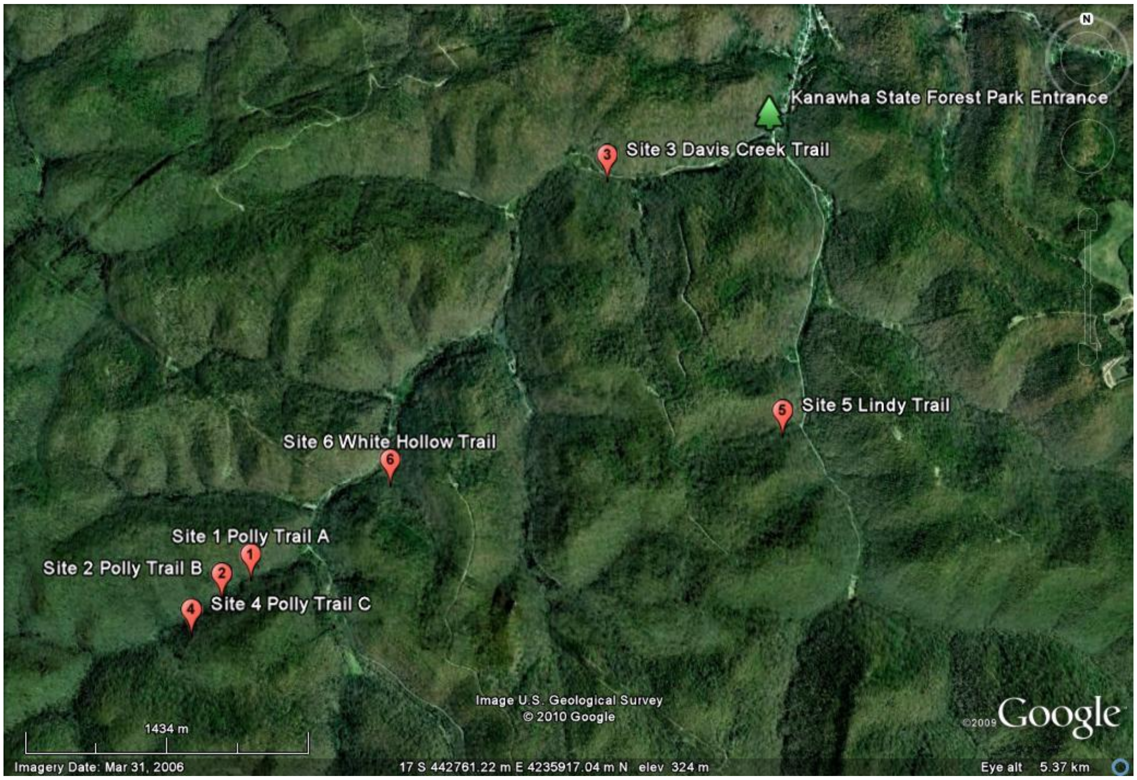

Figure 4. Study sites at Kanawha State Forest, Kanawha County, West Virginia.

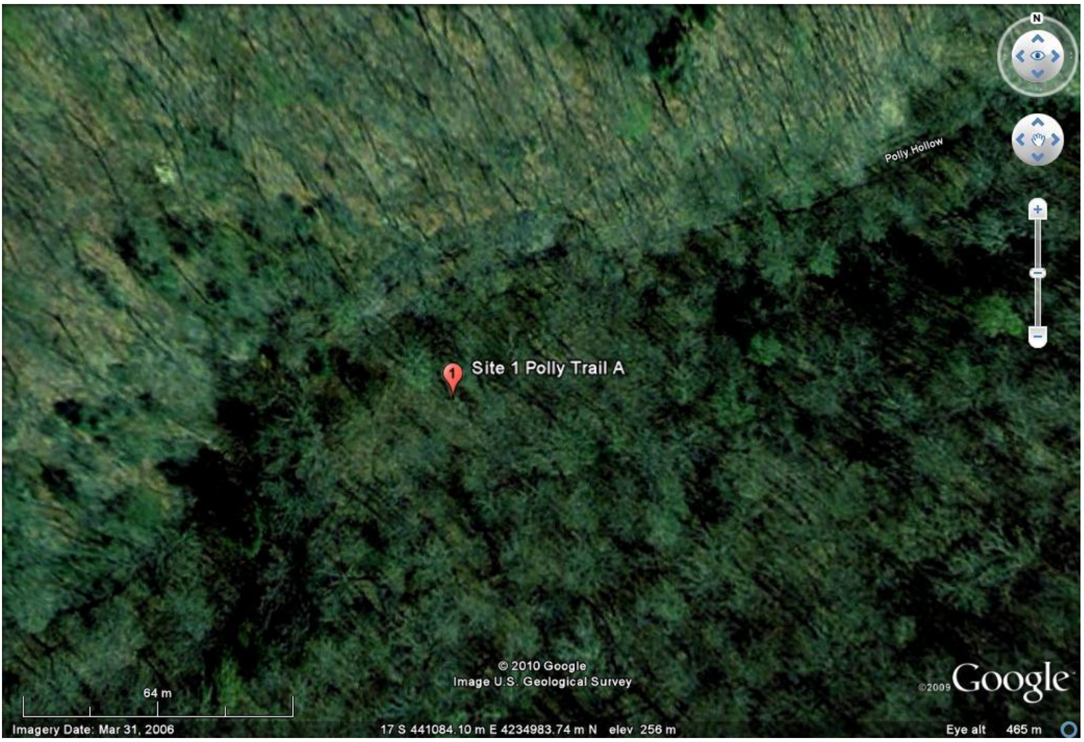

Figure 5. Location of Site 1 Polly Trail A in Kanawha State Forest, Kanawha County, West Virginia.

Figure 6. Emergent rock at Site 1 Polly Trail A, Kanawha State Forest, Kanawha County, West Virginia. Photo taken April 2009 by Sarah E. Miloski.

Figure 7 Location of Site 2 Polly Trail B in Kanawha State Forest, Kanawha County, West Virginia.

Figure 8 Emergent rock at Site 2 Polly Trail B, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

Figure 9 Emergent rock at Site 2 Polly Trail B, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

Figure 10. Emergent rock at Site 2 Polly Trail B, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

Figure 11. Location of Site 3 Davis Creek Trail in Kanawha State Forest, Kanawha County, West Virginia.

Figure 12 Emergent rock at Site 3 Davis Creek Trail, Kanawha State Forest, Kanawha County, West Virginia. Photo taken April 2009 by Sarah E. Miloski.

Figure 13. Location of Site 4 Polly Trail C in Kanawha State Forest, Kanawha County, West Virginia.

Figure 14 Site 4 Polly Trail C, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

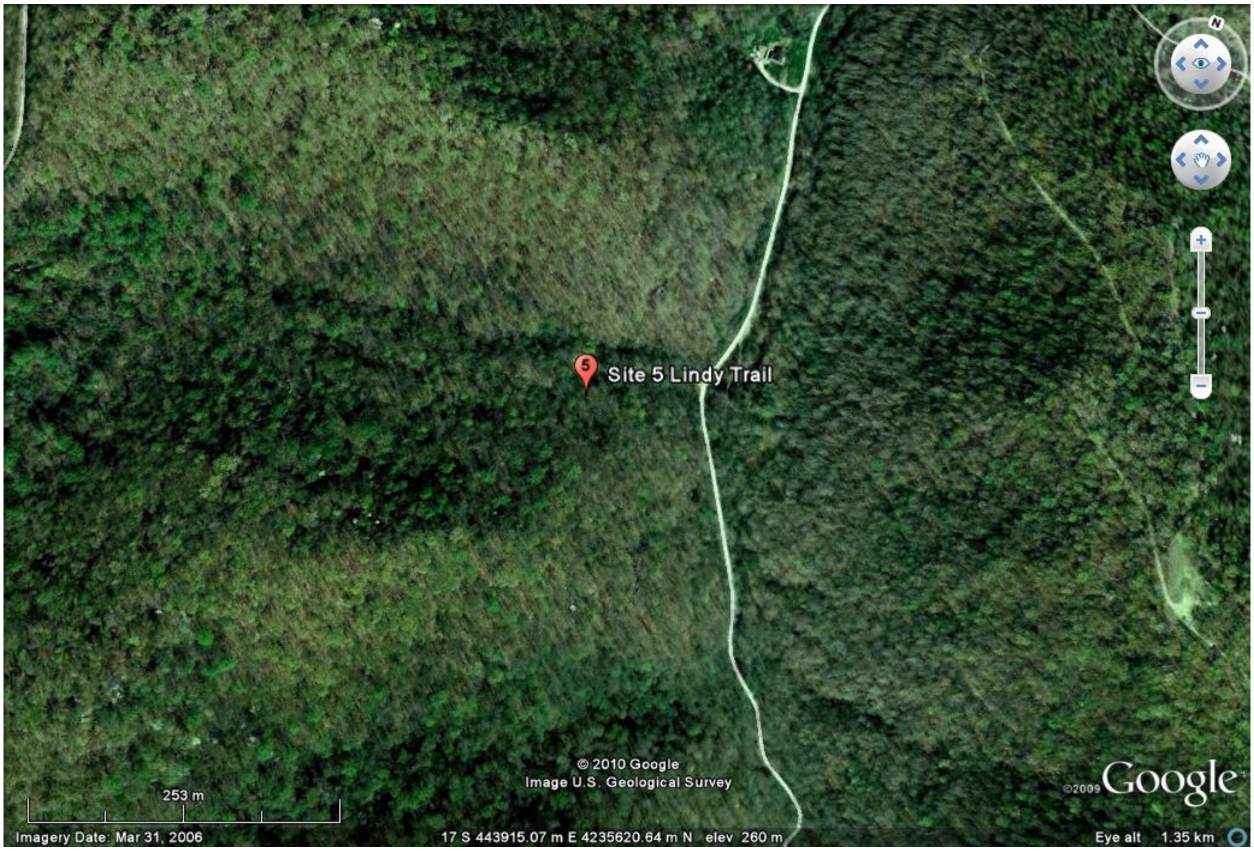

Figure 15. Location of Site 5 Lindy Trail in Kanawha State Forest, Kanawha County, West Virginia.

Figure 16 Site 5 Lindy Trail, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

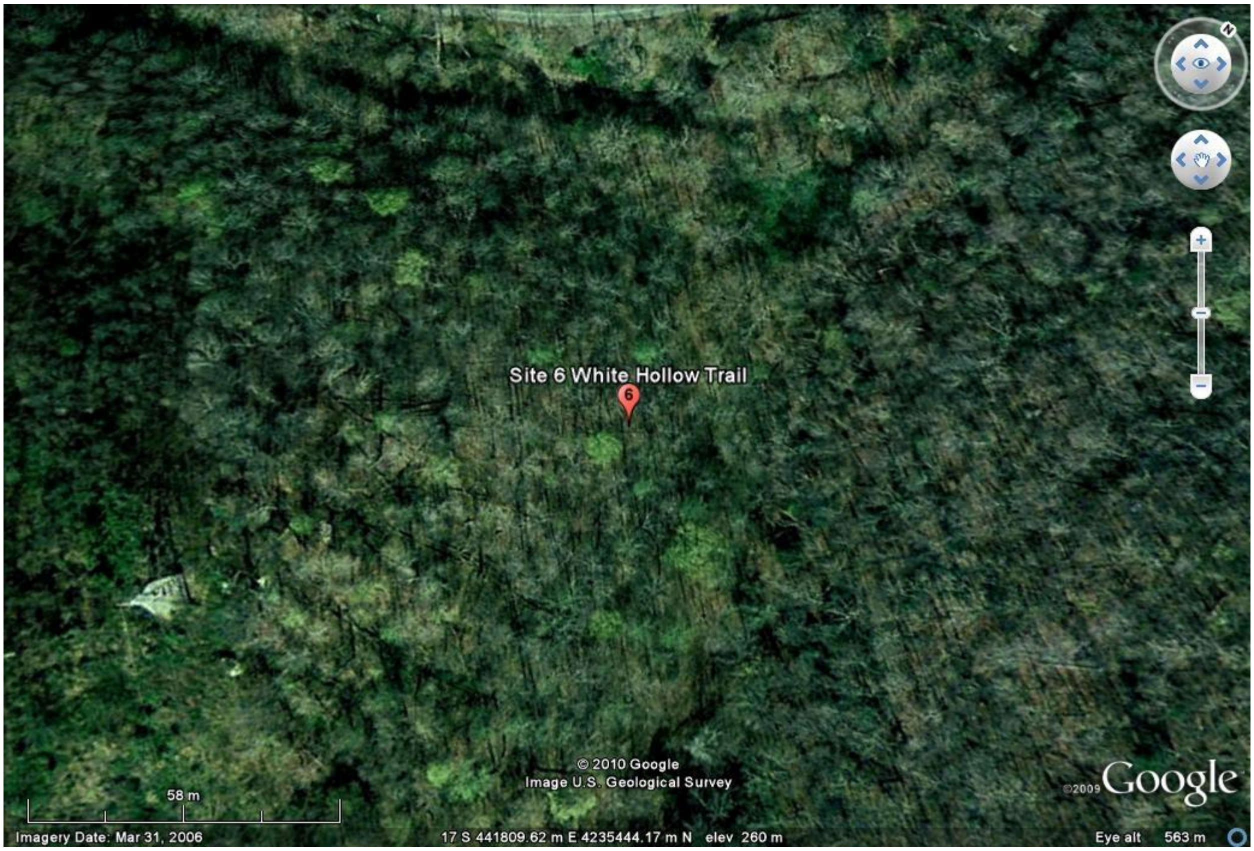

Figure 17. Location of Site 6 White Hollow Trail in Kanawha State Forest, Kanawha County, West Virginia.

Figure 18. Site 6 White Hollow Trail, Kanawha State Forest, Kanawha County, West Virginia. Photo taken September 2009 by Sarah E. Miloski.

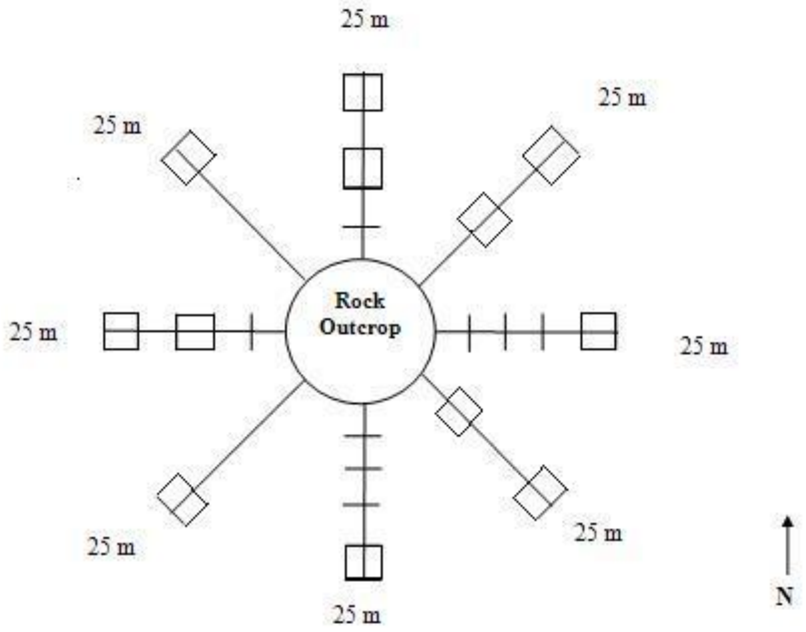

Figure 19. Diagram of 5 m X 5 m plots constructed for vegetation analyses within each site.

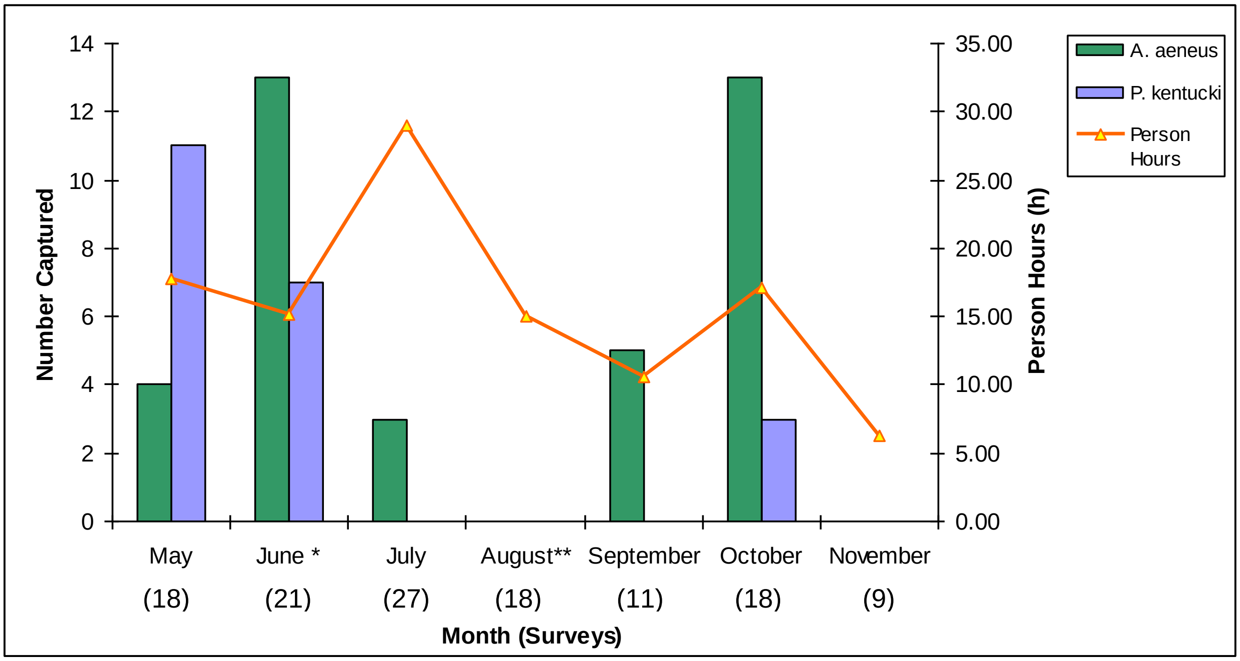

Figure 20. Monthly captures of salamanders during surveys. Numbers in parentheses below each month refer to the number of surveys conducted during the respective month between May 2009 and November 2009. Number captured refers to number of each species.

* Person Hours were not recorded for 9 surveys.

** Although no salamanders were captured in August by means of area constrained searches. I tracked 2 *A. aeneus* found during burlap surveys (Refer to page 29).

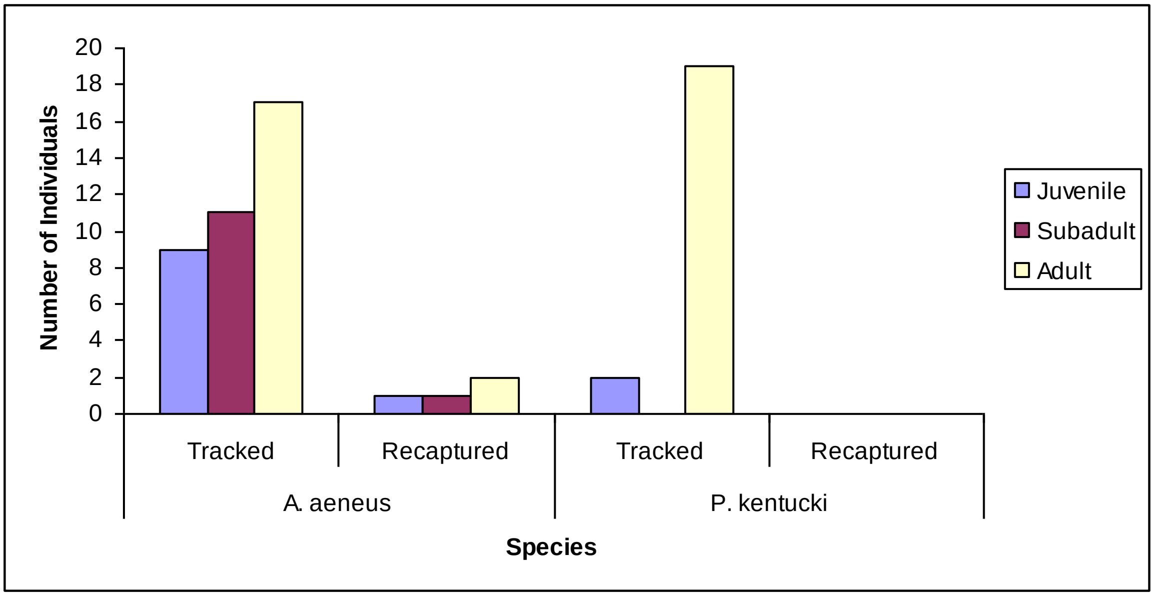

Figure 21. Number of individuals tracked and recaptured per size class of each species.

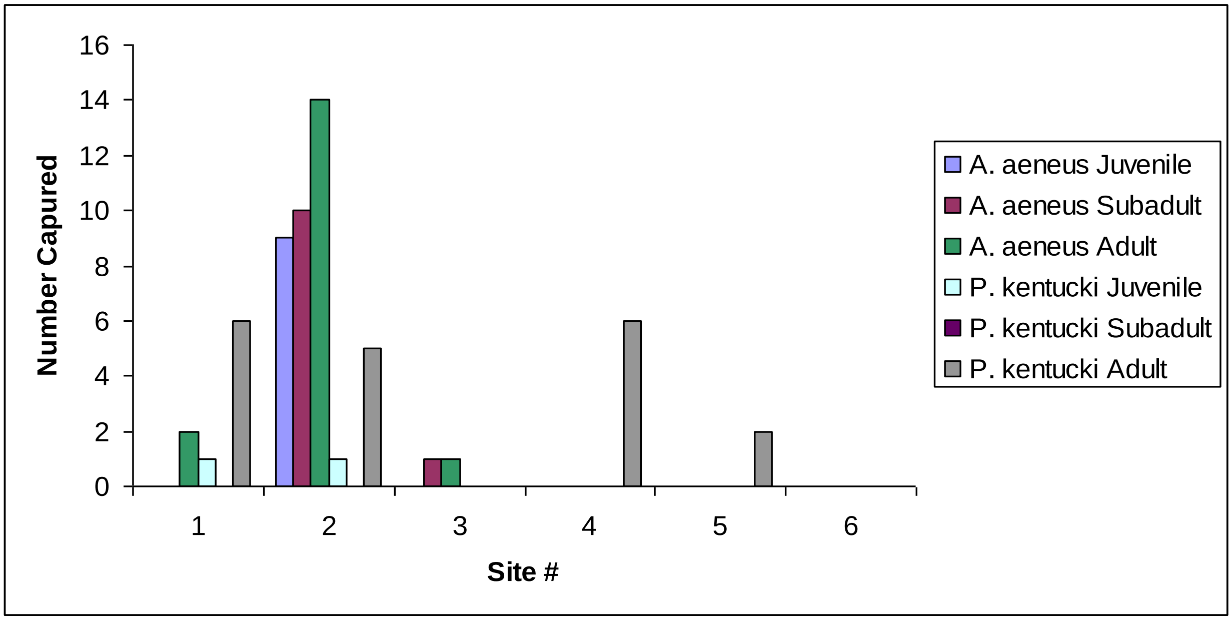

Figure 22. Number captured of each size class per species at each site.

Figure 23. Female *A. aeneus* brooding eggs in crevice at study site in Kanawha County, West Virginia. Photo taken 28 June 2009 by Sarah E. Miloski.


Figure 24. *A. aeneus* hatchling on log on top of emergent rock in Kanawha County, West Virginia. Photo taken 8 Oct 2009 by Sarah E. Miloski.

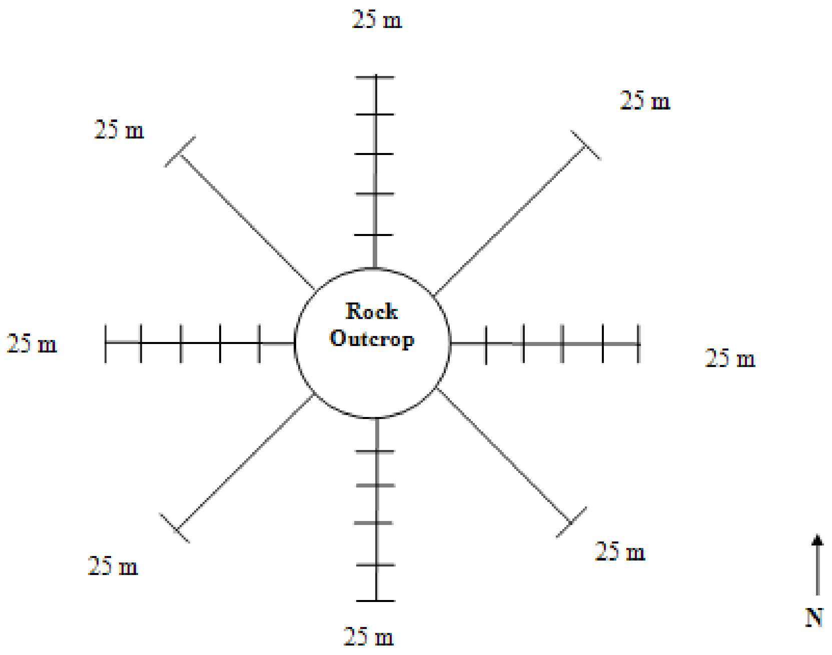

Figure 25. Design of circular plots used for transect surveys. Hachured lines indicate 5 m and where I fastened burlap. The non-hachured lines indicate non-burlap transects on which I marked a tree at 5 m.

Figure 26. Photo of data logger set up. Each site had 1 data logger placed on a tree to collect ambient temperature and relative humidity. I placed 1 data logger under burlap on the same tree to collect temperature and relative humidity under burlap.

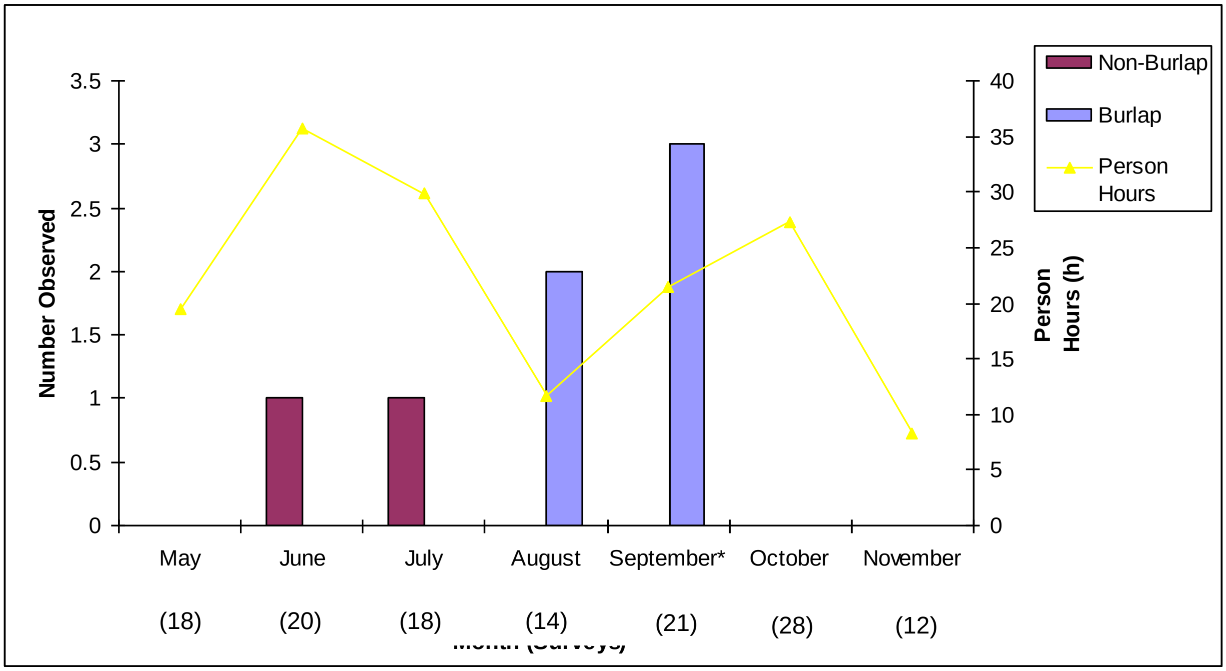

Figure 27. Monthly captures of salamanders on non-burlap trees and burlap trees during the study period. The number in parentheses refers to the number of surveys for the respective month. The line shows person hours spent conducting surveys.
* Indicates 2 *A. aeneus* were found using burlap on the same tree.

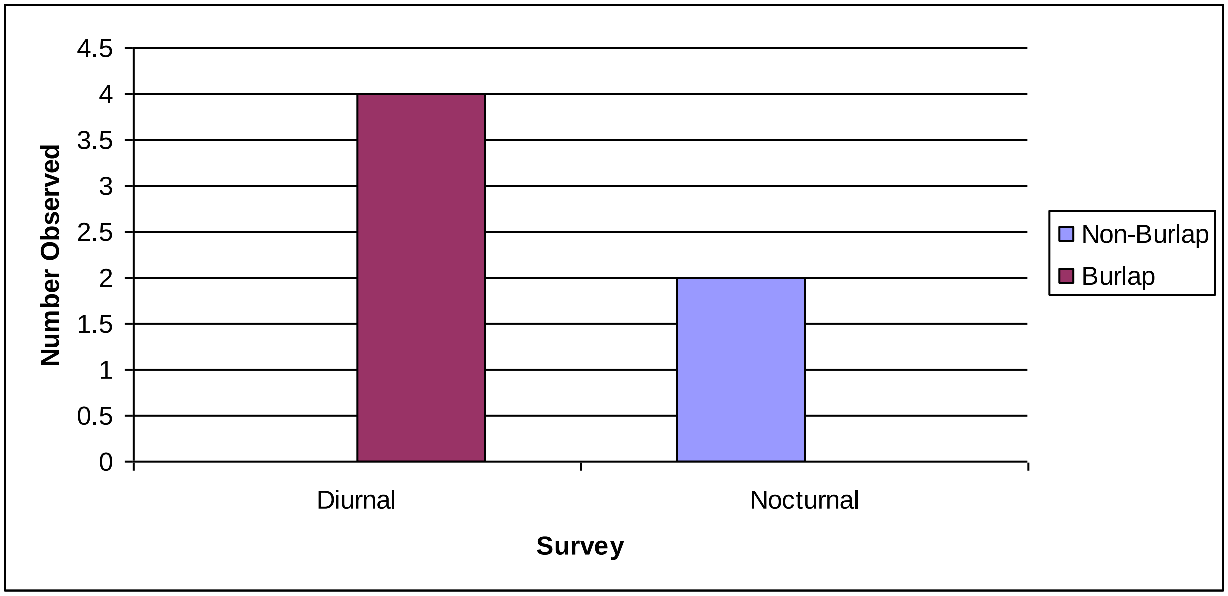

Figure 28. Number of *A. aeneus* observed by survey type.

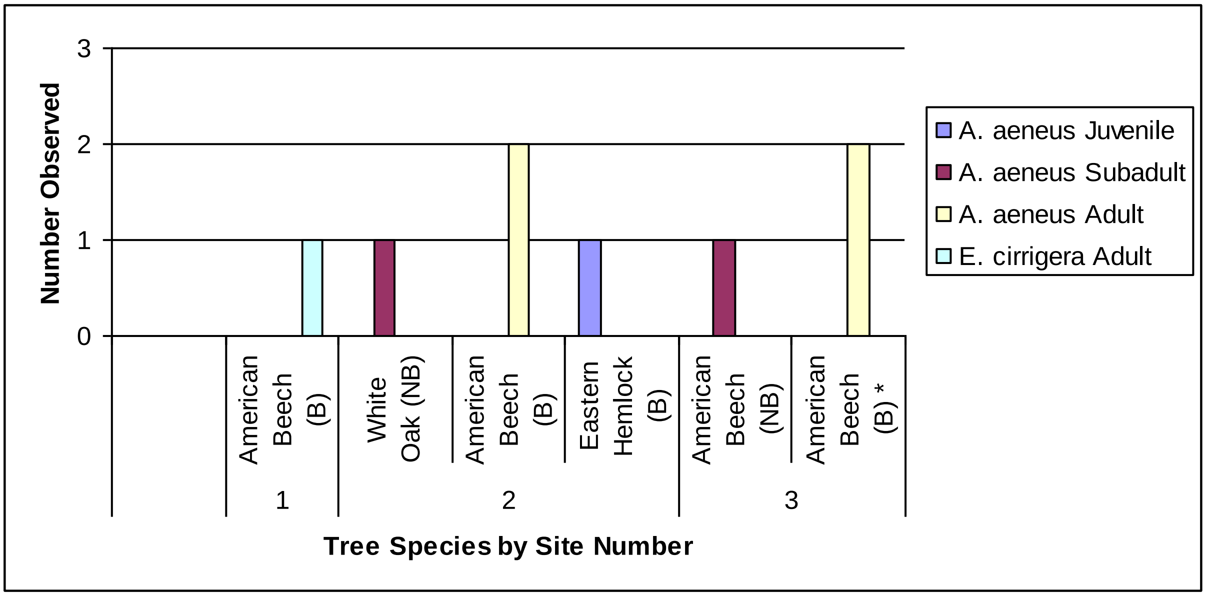

Figure 29. Salamander observations on trees by site. “B” indicates tree with attached burlap. “NB” indicates tree with no attached burlap.
* Indicates 2 *A. aeneus* were found using burlap on the same tree.

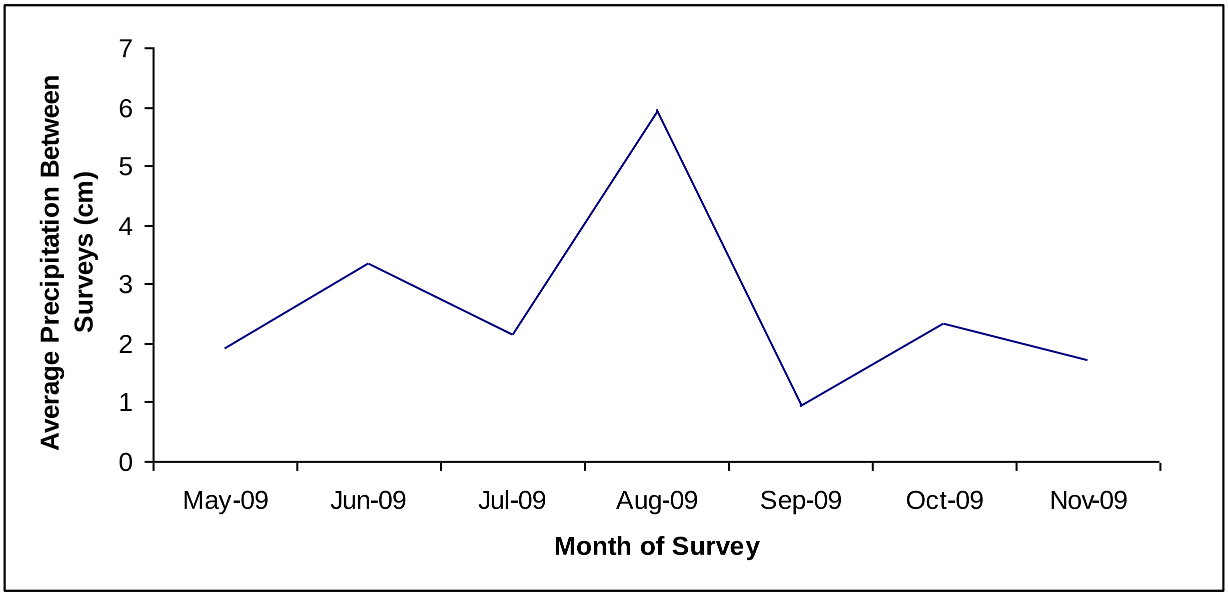

Figure 30. Average precipitation between surveys in the study area from May to November 2009.

APPENDIX : Transect Tree Information

Site #	Position	Tree #	Burlap	Species Name	DBH
1	1 N	1	B	*Liriodendron tulipifera*	20
1	2 N	2	B	*Quercus alba*	70
1	3 N	3	B	*Fagus grandifolia*	25
1	4 N	4	B	*Fagus grandifolia*	10
1	5 N	5	B	*Fagus grandifolia*	15
1	1 NE	6	NB	*Quercus rubra*	50
1	2 NE	7	NB	*Tilia americana*	25
1	3 NE	8	NB	*Fagus grandifolia*	10
1	4 NE	9	NB	*Quercus rubra*	26
1	5 NE	10	NB	*Fagus grandifolia*	40
1	1 E	11	B	*Quercus rubra*	35
1	2 E	12	B	*Fagus grandifolia*	25
1	3 E	13	B	*Fagus grandifolia*	15
1	4 E	14	B	*Quercus alba*	50
1	5 E	15	B	*Liriodendron tulipifera*	25
1	1 SE	16	NB	*Juglans nigra*	40
1	2 SE	17	NB	*Fagus grandifolia*	8
1	3 SE	18	NB	*Fagus grandifolia*	13
1	4 SE	19	NB	*Fagus grandifolia*	13
1	5 SE	20	NB	*Acer saccharum*	10
1	1 S	21	B	*Juglans nigra*	18
1	2 S	22	B	*Fagus grandifolia*	10
1	3 S	23	B	*Fagus grandifolia*	16
1	4 S	24	B	*Fagus grandifolia*	8
1	5 S	25	B	*Acer saccharum*	15
1	1 SW	26	NB	*Acer rubrum*	15
1	2 SW	27	NB	*Quercus alba*	40
1	3 SW	28	NB	*Liriodendron tulipifera*	15
1	4 SW	29	NB	*Juglans nigra*	30
1	5 SW	30	NB	*Fagus grandifolia*	22
1	1 W	31	B	*Quercus alba*	45
1	2 W	32	B	*Acer saccharum*	10
1	3 W	33	B	*Quercus alba*	55
1	4 W	34	B	*Quercus rubra*	62
1	5 W	35	B	*Acer saccharum*	55
1	1 NW	36	NB	*Fagus grandifolia*	10
1	2 NW	37	NB	*Fagus grandifolia*	15
1	3 NW	38	NB	*Quercus alba*	20
1	4 NW	39	NB	*Tsuga canadensis*	25
1	5 NW	40	NB	*Fagus grandifolia*	35
2	1 N	41	B	*Tsuga canadensis*	20
2	2 N	42	B	*Fagus grandifolia*	12
2	3 N	43	B	*Fagus grandifolia*	75
2	4 N	44	B	*Tsuga canadensis*	10

Site #	Position	Tree #	Burlap	Species Name	DBH
2	1 NE	45	NB	*Liriodendron tulipifera*	75
2	2 NE	46	NB	*Fagus grandifolia*	30
2	3 NE	47	NB	*Fagus grandifolia*	50
2	4 NE	48	NB	*Fagus grandifolia*	50
2	5 NE	49	NB	*Tsuga canadensis*	50
2	1 E	50	B	*Tsuga canadensis*	20
2	2 E	51	B	*Acer rubrum*	16
2	3 E	52	B	*Liriodendron tulipifera*	55
2	4 E	53	B	*Quercus alba*	50
2	5 E	54	B	*Fagus grandifolia*	45
2	1 SE	55	NB	*Tsuga canadensis*	22
2	2 SE	56	NB	*Fagus grandifolia*	8
2	3 SE	57	NB	*Tsuga canadensis*	25
2	4 SE	58	NB	*Fagus grandifolia*	52
2	5 SE	59	NB	*Tsuga canadensis*	10
2	1 S	60	B	*Tsuga canadensis*	17
2	2 S	61	B	*Tsuga canadensis*	23
2	3 S	62	B	*Tsuga canadensis*	32
2	4 S	63	B	*Acer rubrum*	25
2	5 S	64	B	*Tsuga canadensis*	15
2	1 SW	65	NB	*Quercus alba*	40
2	2 SW	66	NB	*Fagus grandifolia*	10
2	3 SW	67	NB	*Quercus alba*	45
2	4 SW	68	NB	*Quercus alba*	80
2	5 SW	69	NB	*Quercus alba*	40
2	1 W	70	B	*Tsuga canadensis*	18
2	2 W	71	B	*Tsuga canadensis*	17
2	3 W	72	B	*Tsuga canadensis*	18
2	4 W	73	B	*Tsuga canadensis*	25
2	5 W	74	B	*Fagus grandifolia*	17
2	1 NW	75	NB	*Tsuga canadensis*	8
2	2 NW	76	NB	*Quercus alba*	60
2	3 NW	77	NB	*Tsuga canadensis*	27
2	4 NW	78	NB	*Tsuga canadensis*	70
2	5 NW	79	NB	*Tsuga canadensis*	75
3	1 N	80	B	*Fagus grandifolia*	8
3	2 N	81	B	*Fagus grandifolia*	10
3	3 N	82	B	*Fagus grandifolia*	10
3	4 N	83	B	*Fagus grandifolia*	8
3	5 N	84	B	*Fagus grandifolia*	8
3	1 NE	85	NB	*Fagus grandifolia*	30
3	2 NE	86	NB	*Fagus grandifolia*	76
3	3 NE	87	NB	*Fagus grandifolia*	45
3	4 NE	88	NB	*Fagus grandifolia*	45
3	5 NE	89	NB	*Fagus grandifolia*	45
3	1 E	90	B	*Fagus grandifolia*	30
3	2 E	91	B	*Acer saccharum*	7

Site #	Position	Tree #	Burlap	Species Name	DBH
3	3 E	92	B	*Acer saccharum*	8
3	4 E	93	B	*Acer saccharum*	8
3	5 E	94	B	*Acer saccharum*	18
3	1 SE	95	NB	*Acer saccharum*	4
3	2 SE	96	NB	*Quercus alba*	50
3	3 SE	97	NB	*Acer saccharum*	22
3	4 SE	98	NB	*Acer saccharum*	18
3	5 SE	99	NB	*Acer saccharum*	22
3	1 S	100	B	*Acer saccharum*	8
3	2 S	101	B	*Acer saccharum*	18
3	3 S	102	B	*Acer saccharum*	10
3	4 S	103	B	*Tilia americana*	30
3	5 S	104	B	*Acer saccharum*	12
3	1 SW	105	NB	*Acer saccharum*	32
3	2 SW	106	NB	*Acer saccharum*	10
3	3 SW	107	NB	*Acer saccharum*	22
3	4 SW	108	NB	*Acer saccharum*	8
3	5 SW	109	NB	*Acer saccharum*	20
3	1 W	110	B	*Fagus grandifolia*	60
3	2 W	111	B	*Acer saccharum*	4
3	3 W	112	B	*Acer saccharum*	4
3	4 W	113	B	*Quercus alba*	20
3	5 W	114	B	*Acer saccharum*	12
3	1 NW	115	NB	*Fagus grandifolia*	4
3	2 NW	116	NB	*Fagus grandifolia*	4
3	3 NW	117	NB	*Fagus grandifolia*	32
3	4 NW	118	NB	*Fagus grandifolia*	50
3	5 NW	119	NB	*Acer saccharum*	8
4	1 N	120	B	*Tsuga canadensis*	28
4	2 N	121	B	*Juglans nigra*	25
4	3 N	122	B	*Quercus alba*	75
4	4 N	123	B	*Tsuga canadensis*	15
4	5 N	124	B	*Fagus grandifolia*	10
4	1 NE	125	NB	*Fagus grandifolia*	20
4	2 NE	126	NB	*Fagus grandifolia*	22
4	3 NE	127	NB	*Tsuga canadensis*	15
4	4 NE	128	NB	*Tsuga canadensis*	25
4	5 NE	129	NB	*Fagus grandifolia*	45
4	1 E	130	B	*Quercus alba*	16
4	2 E	131	B	*Tilia americana*	15
4	3 E	132	B	*Acer rubrum*	20
4	4 E	133	B	*Acer rubrum*	12
4	5 E	134	B	*Acer rubrum*	20
4	1 SE	135	NB	*Fagus grandifolia*	27
4	2 SE	136	NB	*Fagus grandifolia*	30
4	3 SE	137	NB	*Tilia americana*	25
4	4 SE	138	NB	*Fagus grandifolia*	8

Site #	Position	Tree #	Burlap	Species Name	DBH
4	5 SE	139	NB	*Tsuga canadensis*	20
4	1 S	140	B	*Fagus grandifolia*	20
4	2 S	141	B	*Liriodendron tulipifera*	12
4	3 S	142	B	*Acer rubrum*	23
4	4 S	143	B	*Juglans nigra*	10
4	5 S	144	B	*Fagus grandifolia*	15
4	1 SW	145	NB	*Tsuga canadensis*	16
4	2 SW	146	NB	*Fagus grandifolia*	15
4	3 SW	147	NB	*Quercus alba*	20
4	4 SW	148	NB	*Quercus alba*	30
4	5 SW	149	NB	*Tsuga canadensis*	15
4	1 W	150	B	*Tilia americana*	10
4	2 W	151	B	*Quercus alba*	16
4	3 W	152	B	*Tsuga canadensis*	25
4	4 W	153	B	*Tsuga canadensis*	15
4	5 W	154	B	*Tsuga canadensis*	30
4	1 NW	155	NB	*Tsuga canadensis*	26
4	2 NW	156	NB	*Tsuga canadensis*	15
4	3 NW	157	NB	*Tsuga canadensis*	25
4	4 NW	158	NB	*Tsuga canadensis*	25
4	5 NW	159	NB	*Fagus grandifolia*	26
5	1 N	160	B	*Fagus grandifolia*	50
5	2 N	161	B	*Fagus grandifolia*	20
5	3 N	162	B	*Fagus grandifolia*	10
5	4 N	163	B	*Tilia americana*	24
5	5 N	164	B	*Fagus grandifolia*	15
5	1 NE	165	NB	*Acer saccharum*	35
5	2 NE	166	NB	*Acer saccharum*	14
5	3 NE	167	NB	*Quercus alba*	80
5	4 NE	168	NB	*Acer saccharum*	20
5	5 NE	169	NB	*Acer saccharum*	20
5	1 E	170	B	*Acer saccharum*	15
5	2 E	171	B	*Tilia americana*	45
5	3 E	172	B	*Acer saccharum*	25
5	4 E	173	B	*Fagus grandifolia*	10
5	5 E	174	B	*Fagus grandifolia*	15
5	1 SE	175	NB	*Acer saccharum*	18
5	2 SE	176	NB	*Acer saccharum*	3
5	3 SE	177	NB	*Fagus grandifolia*	7
5	4 SE	178	NB	*Tilia americana*	65
5	5 SE	179	NB	*Juglans nigra*	35
5	1 S	180	B	*Tilia americana*	75
5	2 S	181	B	*Acer saccharum*	10
5	3 S	182	B	*Acer saccharum*	20
5	4 S	183	B	*Juglans nigra*	36
5	5 S	184	B	*Acer saccharum*	13
5	1 SW	185	NB	*Tilia americana*	65
5	2 SW	186	NB	*Acer saccharum*	8

Site #	Position	Tree #	Burlap	Species Name	DBH
5	3 SW	187	NB	*Fagus grandifolia*	8
5	4 SW	188	NB	*Acer saccharum*	10
5	5 SW	189	NB	*Fagus grandifolia*	18
5	1 W	190	B	*Acer saccharum*	10
5	2 W	191	B	*Fagus grandifolia*	15
5	3 W	192	B	*Tilia americana*	30
5	4 W	193	B	*Acer saccharum*	10
5	5 W	194	B	*Tilia americana*	15
5	1 NW	195	NB	*Fagus grandifolia*	18
5	2 NW	196	NB	*Tilia americana*	45
5	3 NW	197	NB	*Acer saccharum*	35
5	4 NW	198	NB	*Acer saccharum*	30
5	5 NW	199	NB	*Juglans nigra*	55
6	1 N	200	B	*Acer saccharum*	33
6	2 N	201	B	*Acer saccharum*	15
6	3 N	202	B	*Acer saccharum*	15
6	4 N	203	B	*Acer saccharum*	33
6	5 N	204	B	*Acer saccharum*	25
6	1 NE	205	NB	*Tilia americana*	33
6	2 NE	206	NB	*Tilia americana*	13
6	3 NE	207	NB	*Tilia americana*	33
6	4 NE	208	NB	*Acer saccharum*	49
6	5 NE	209	NB	*Acer saccharum*	37
6	1 E	210	B	*Acer saccharum*	8
6	2 E	211	B	*Tilia americana*	55
6	3 E	212	B	*Acer saccharum*	8
6	4 E	213	B	*Tilia americana*	33
6	5 E	214	B	*Acer saccharum*	8
6	1 SE	215	NB	*Acer saccharum*	10
6	2 SE	216	NB	*Tilia americana*	30
6	3 SE	217	NB	*Fagus grandifolia*	17
6	4 SE	218	NB	*Acer saccharum*	10
6	5 SE	219	NB	*Liriodendron tulipifera*	18
6	1 S	220	B	*Tilia americana*	25
6	2 S	221	B	*Acer saccharum*	7
6	3 S	222	B	*Quercus rubra*	20
6	4 S	223	B	*Acer saccharum*	11
6	5 S	224	B	*Acer saccharum*	16
6	1 SW	225	NB	*Tilia americana*	62
6	2 SW	226	NB	*Acer saccharum*	5
6	3 SW	227	NB	*Acer saccharum*	31
6	4 SW	228	NB	*Acer saccharum*	7
6	5 SW	229	NB	*Acer saccharum*	33
6	1 W	230	B	*Acer saccharum*	13
6	2 W	231	B	*Acer saccharum*	10
6	3 W	232	B	*Acer saccharum*	13
6	4 W	233	B	*Acer rubrum*	23
6	5 W	234	B	*Acer saccharum*	20

Site #	Position	Tree #	Burlap	Species Name	DBH
6	1 NW	235	NB	*Acer saccharum*	13
6	2 NW	236	NB	*Acer saccharum*	8
6	3 NW	237	NB	*Acer saccharum*	23
6	4 NW	238	NB	*Fagus grandifolia*	20
6	5 NW	239	NB	*Fagus grandifolia*	20