THE EFFECTS OF RHODODENDRON ON SALAMANDER COMMUNITIES IN THE NANTAHALA MOUNTAINS

A thesis presented to the Graduate School of Western Carolina University in partial fulfillment of the requirements for a degree of Master of Science in Biology.

By

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ABSTRACT

The effects of rhododendron on salamander communities in the Nantahala Mountains.

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Rhododendron or great laurel is a common evergreen shrub found throughout eastern North America. Although native, rhododendron has been increasing in the Southern Appalachian Mountains landscape due to fire suppression, logging, and loss of the American chestnut. It now has the potential to affect a larger variety of ecosystems and species that it did historically. Salamanders of the family Plethodontidae are highly diverse in the Southern Appalachian Mountains. They are known to be sensitive to their environment and are often considered to be potential indicators of ecosystem changes. Rhododendron has known effects on plants, soil nutrients, and leaf litter macroinvertebrates. The expansion of rhododendron may play an important role in determining terrestrial and aquatic salamander community structure and population dynamics. This study aimed to see how rhododendron affects salamander communities in sites in the Nantahala Mountains of western North Carolina. Initially, four sites were chosen in the upper Nantahala River watershed to conduct a mark-recapture study. Sites were divided into two plots; one within a rhododendron thicket and one in the larger forest matrix, both alongside small streams. After collecting data in 2009, concerns from highly variable population estimates and differences in detection between rhododendron and non-rhododendron plots with the mark-recapture study led to methods being changed in 2010 to removal sampling to ameliorate these concerns. Population estimates from removal sampling varied greatly amongst sites and were not significantly different between rhododendron and non-rhododendron plots. Overall, red-legged and ocoee salamanders were the most abundant species across all sites. Rhododendron does not appear to have a net effect on salamander population sizes. Rhododendron does appear to reduce people’s ability to find salamanders and may have negative influences in studies that do not account for differences in detection between plots in and outside of rhododendron thickets.

INTRODUCTION

Great laurel, also known as rosebay rhododendron or simply rhododendron, (*Rhododendron maximum*) is a common evergreen ericaceous shrub native to the eastern United States and southeastern Canada. Rhododendron tends to form dense thickets in the subcanopy and is a dominant species in many locations. The loss of the American chestnut (*Castanea dentata*) from the overstory, fire suppression, and intensive logging have been suggested to have resulted in increases in rhododendron density, thicket size, and habitat types occupied in southern Appalachian forests (Phillips & Murdy 1985; Van Lear, Vandermast, Rivers, Baker, Hedman, Clinton & Waldrop 2001; Vandermast, Van Lear & Clinton 2002). The increase in rhododendron across the southern Appalachian landscape is likely leading to changes in community structure.

Where it occurs, rhododendron tends to greatly alter the plant community and soil nutrients (Nilsen, Clinton, Lei, Miller, Semones & Walker 2001). Herbaceous plants and tree sapling regeneration are greatly reduced under rhododendron canopies (Phillips & Murdy 1985; Baker & Van Lear 1998; Nilsen et al. 2001; Vandermast & Van Lear 2002; Lei, Nilsen & Semones 2006; Wurzburger & Hendrick 2007). Litter with rhododendron leaves contains fewer overall microathropods (Hoover & Crossley 1995). Rhododendron litter also increases the bulk organic matter in soils by lowering organic matter decomposition and reducing the number of leaf litter decomposers to break leaves down into useable components (Hoover & Crossley 1995; Wurzburger & Hendrick 2007). It also alters mineral dynamics by altering where the abundance of key nutrients, like nitrogen, are concentrated in the soil horizon, and increases carbon because of reduced litter decomposition rates (Hoover & Crossley, 1995). Rhododendron reduces the availability of nutrients in the soil by consuming more than other plants in the area (Nilsen et al. 2001). In short, rhododendron greatly alters the structure and flows of ecosystems where it dominates, thus altering the environments in which it grows.

Rhododendron is also predicted to play an important role in streamside communities as the eastern hemlock (*Tsuga canadensis*) dies off and is effectively removed from cove forest canopies by the hemlock wooly adelgid (*Adelges tsugae*) (Spaulding & Rieske 2010). Rhododendron, which is already common underneath hemlock canopies, may help keep the forest floor and streams shaded after the loss of the hemlock canopy; partially alleviating the warming of Southern Appalachian streams. The loss of hemlocks may also create a secondary push, such as that seen after the loss of American chestnut, for further expansion of rhododendron and potentially create a more heath-like community in areas where hemlock cove forests once dominated (Spaulding & Rieske 2010).

Although much research has examined the effects of rhododendron on plant communities and ecosystem cycling, little is known about the potential effects of rhododendron on other components of ecosystems, particularly vertebrate animals. Many salamanders, especially those of the family Plethodontidae, are known to be very sensitive to their environment and occur in high abundances in North American forests. Plethodontids are thus considered to have great potential for use as bioindicators (Welsh & Ollivier 1998; Welsh & Droege 2001). In particular, Plethodontid salamanders are reliant upon moist conditions to breathe and are highly susceptible to desiccation (Spotila 1972). Plethodontid salamanders are particularly diverse in the Southern Appalachian

Mountains (Petranka 1998), the very area where rhododendron has expanded extensively. While both rhododendron and the native Plethodontid salamanders have co-existed in the same region, the heterogeneity of the landscape may have allowed salamanders to either avoid or exploit rhododendron thickets depending on its suitability as habitat for a given species. Different salamander species may have different tolerances to the conditions found under rhododendron canopies.

The effects of rhododendron on the environment could affect salamanders in a number of ways. The reduction of leaf litter microarthropods and altering of nutrient flows such that Carbon is increased could reduce the availability and nutritional content of food for salamanders. Additionally, the phenolic compounds found in rhododendron leaves can potentially be harmful to salamanders. However, the dense canopy and reduction in litter decomposition could also make living under a rhododendron thicket more stable for salamanders in terms of soil and leaf litter moisture as compared to the surrounding environment. The expansion of rhododendron has the potential to play an important role in determining terrestrial salamander population and community structure. Furthermore, the loss of eastern hemlocks along Southern Appalachian streams is predicted to cause further expansion of cover and density of rhododendron (Spaulding & Reiske 2010). Therefore, rhododendron has an increasing potential to affect salamander communities and populations in the Southern Appalachians.

Study Rational and Questions

The main purpose of this study was to assess if rhododendron has an effect on terrestrial salamander populations. More specifically, I aimed to answer the broad question: Does rhododendron have an effect on salamander population densities? After weighing the potential pros and cons of rhododendron on salamanders (i.e. reduced prey, lower quality prey, negative interactions with phenolic compounds vs. increased shade, etc.) and anecdotal evidence from talking with experts and personal experience, I hypothesized that rhododendron has a negative effect on salamanders. I conducted the study in the high elevation salamander communities in the Nantahala Mountains of the Appalachians because this area had yet to have any major published work regarding terrestrial salamander population sizes in the higher elevations. This would also allow me to secondarily answer the question: What are the salamander population densities in the Nantahala Mountains? For this question, I expected the densities to be similar to other studies in the Southern Appalachian Mountain range.

METHODS

General Overview, Site Selection and Research Site Setup

To test my hypothesis, I decided I would need to know the relative size of salamander populations, and initially decided to use mark-recapture as this has previously been shown to be a relatively reliable means of determining salamander population size (Bailey, Simons & Pollock 2004 a&b). However, due to large uncertainty in the confidence intervals for the population estimates from my initial mark-recapture work and differences in capture probabilities between plot types, I later switched to removal sampling. I reasoned that, because removal sampling reduces the population present in the enclosure and requires that a large proportion of the population be removed in order for reliable estimates to be obtained, population estimates derived from removal would compensate for the detection differences and yield comparable population estimates between the two plot types. I also recorded a few general habitat characteristics that I could use to see how rhododendron may affect salamander populations. These habitat characteristics would also allow me to compare some of the differences between rhododendron and non-rhododendron sites and confirm that my rhododendron sites have similar characteristics to other studies with rhododendron.

In order to test my questions, I searched for sites with and without sizeable rhododendron thickets within the same forest stand. Forest stands of ages of about 70 years or older were chosen as this has been estimated to be the time needed for salamander populations to completely recover from clear cutting events (Petranka Eldridge & Haley 1993). I chose sites dominated by hardwoods between elevations of about 1100 and 1300 meters, within the upper Nantahala River drainage (to allow ease of travel between sites) in Macon and Clay Counties of North Carolina (Table 1). All plots were associated with nearby second order streams. Initially, I settled on four sites (Deep Gap, Wine Springs, Glade Branch, and Hogan Branch), as these four sites appeared to be similar and fit the above criteria.

Initially for the 2009 mark-recapture study, I selected two 20m by 20m plots along a stream edge within each site; one within a rhododendron thicket and without rhododendron. Plots were further divided into 5m by 5m cells using small flags for better ease in determining salamander locations. In 2010 when methods were altered, Wine Springs was removed as a site to reduce travel among sites because the intense nature of removal sampling required greater attention and more time be spent at each site. For removal sampling, plots were divided into four 5m by 5m squares approximately 10-20 meters from the stream edge. Each 5m by 5m square was completely enclosed in silt fencing that was approximately 70 cm tall and 10-15 cm below ground where possible. If the roots of trees were too large to cut through, the edge of the silt fencing was stapled to the root. Winged barriers were secured with duct tape and staples to the upper edge of the fences to prevent vertical movement of salamanders over the fence in both directions.

Habitat Characteristics

Three major habitat variables: herbaceous plant cover, soil moisture, and leaf litter depth were measured as these were potentially important to salamanders and/or would help confirm differences between rhododendron and non-rhododendron plots. Percent herbaceous plant cover was measured from three randomly selected $1m^2$ samples from within each enclosure in 2010. Percent herbaceous cover was then averaged for each site-plot type combination. Soil moisture was measured using a time domain reflectometry (TDR) device during salamander removal surveys in 2010 at five haphazardly-selected points within each enclosure. Soil moisture was then averaged for each site-plot type combination. Leaf litter depths were collected in 2009 and measured at the site of capture for each individual salamander by pushing a smaller ruler to the top of the soil layer. All leaf litter data points were then averaged for each site-plot type combination. All habitat-related data were analyzed using a paired T-test to test differences between plot types.

Mark-Recapture Surveys

In 2009, I used a Jolly-Seber multiple mark-recapture approach to estimate salamander population size on each plot (Bailey et al. 2004a&b). I conducted area-constrained surveys for salamanders once a month at each site from July to September 2009, with the exception of Hogan Branch, where a sudden cold snap in September prevented the third survey. I conducted searches beginning half an hour after sunset, beginning with a randomly-selected plot (rhododendron or non-rhododendron) for that site and alternating the next visit. When possible, I completed surveys on wet nights to achieve the highest number of captures possible. I recorded data on survey times, weather, and the names of searchers (typically two to four per survey). I recorded species, location within the grid, height in relation to the ground, object on which it was found, and activity (stationary, moving, climbing, in burrow, etc.) for each salamander to gain information on microhabitat use within each habitat. Salamanders were then brought back to the lab and measured snout-vent length (SVL), weighed, sexed (when possible), and aged (adult or juvenile). I also uniquely marked each individual with VIE fluorescing dye markers (Bailey 2002; Heemeyer, Homyack & Haas 2007) if not previously captured. Unique marks of up to four different colors in up to four locations were made on each individual of a species. Recaptures were recorded. Salamanders were then released at the area of their capture.

I used Program MARK (Cooch & White 2011) to estimate population sizes and capture probabilities using the POPAN model. The POPAN model, a variation of the Jolly-Seber model, assumes an open population, and estimates the super population size, survival, and capture probability. Both time constrained and unconstrained models were run. The best fitting model was used for each plot. Capture probabilities were obtained for *Plethodon shermani* and *Desmognathus ocoee* only. Capture probabilities were averaged for each species by each site and plot type and analyzed using a paired T-test to test differences between plot types.

Salamander Body Condition

Using the 2009 mark-recapture data, I ran a regression of SVL and observed live mass for all individuals of each of the two most common species captured in 2009, *Plethodon shermani* and *Desmognathus ocoee*. I then used the regression equation and the observed SVL of each individual in 2009 to estimate the expected mass of that individual according to the regression equation. I then took the observed mass as a proportion of the expected mass to determine the relative mass of each individual as a measure of their body condition in 2009. According to this measure, individuals with a relative mass greater than one were heavier than expected and those with less than one lighter than expected. I then calculated the average relative mass for each site-plot type combination and analyzed the result using a paired T-test to test for differences between plot types.

Salamander Removal Surveys

Due to previously mentioned concerns about high confidence intervals and differences in capture probabilities resulting from the 2009 mark-recapture study, I decided to switch to a variation of the Leslie removal model for population estimation in 2010. During each removal survey, each enclosure was searched thoroughly starting from half an hour after sunset until all enclosures were thoroughly searched for that site. Sampling consisted of searching an enclosure repeatedly until fewer than five salamanders were found. As many sites were visited a night as was possible, ranging from one to all three sites. During each survey, days since the last rain, and moisture condition of the site were recorded for each survey. Moisture condition was recorded using categories similar to those used by Petranka & Murray (2001): wet for conditions where there were visible drops of water on leaves, damp when there was visible water on the surface of the leaf litter, and dry when no visible water was present on either plants or leaf litter.

During surveys, each captured salamander was tallied by species, for each enclosure, and placed in a bag. At the end of each night’s surveys, the snout-vent length and sex were recorded for each individual. I clipped the middle toe of the right hind foot of each individual before releasing the salamander outside the enclosures. Upon successive surveys, captured salamanders were first inspected to determine if their toe was clipped. They were released outside the enclosure if they were found to be marked or, if unmarked, were tallied and placed in a bag to be measured and marked later.

Determining Population Estimates

I began estimating population sizes after the fifth survey and continued until at least 70% of the total estimated salamander population (all species and enclosures pooled together for that site-plot type combination) were deemed removed. Seventy percent removal was accepted to provide reasonable population estimates with minimal error in a similar study (Petranka & Murray 2001). First, an analysis of variance (ANOVA) was run to determine if there was a significant moisture condition effect on the number of individuals of a species captured per night for site-plot type combination. If there was not, a simple regression of the nightly removed salamander totals versus the cumulative removed salamander totals was run to determine the equation of the trend line (Figure 1). The equation was then solved for x assuming y=0 (no new salamanders found on a nightly survey) to determine the estimated population size. If there was a significant moisture condition effect, an analysis of co-variance (ANCOVA) was run incorporating the moisture condition of each night to determine how the moisture condition impacted nightly capture. Nightly removed salamander values were then corrected to the intermediate (damp) moisture condition and regressed to find the estimated population size using the corrected values.

After initially stopping surveys because the overall population had reached the 70% removal criteria, I began to calculate salamander population estimates for each individual species. I also began to run population estimates for each individual enclosure (enclosure level) for each species and for the total number of salamanders found from that enclosure. I determined that insufficient surveys had been conducted to determine reliable estimates for individual species and enclosures, and more surveys were initiated until at least 65% (reduced to maximize the number of species and enclosures for which estimates could be considered reliable) of the estimated population size was removed for the most common species at that site or time constraints and deteriorating seasonal weather conditions prevented further surveys from being conducted. As a result of these issues, the total number of surveys varied between sites (Deep Gap n=14, Hogan Branch n=11, and Glade Branch n=10).

After obtaining as many reliable population estimates as I could, I decided to estimate the biomass for each estimate. First, I ran a simple regression of the log of the wet-mass and SVL from the 2009 mark-recapture data for each species, site, and plot type to determine if a close relationship (e. g. r^2 near 1) existed (Figure 2). Once a close relationship was established, I used the regression equation to estimate the mean mass for each species and plot type in 2010 using the 2010 removal sampling SVL data. The estimated masses were then used with the population estimates, at enclosure and site levels, to estimate the kg of salamanders per hectare, or the biomass. If an estimate was not possible for a species at all site-plot type combinations, an analysis was not run.

Reliable estimates were not obtained for all species and all enclosures. In all cases, enclosure population or biomass estimates were averaged for each site-plot type combination before being analyzed. Unless otherwise stated, all data were analyzed using a paired T-test to test differences between plot types.

RESULTS

Habitat Characteristics

Herbaceous plant cover varied nearly significantly by plot type (T = 2.787, df = 2, P= 0.054), but also varied greatly between sites. Deep Gap had lower overall herbaceous plant cover in control (non-rhododendron) plots and more in rhododendron plots as compared to Glade Branch and Hogan Branch (Figure 3). Soil moisture did not differ significantly between plot types (T = 1.279, df = 2, P = 0.165, Figure 4). Leaf litter depths did not differ significantly among plot types (T= 1.774, df=3, P= 0.087, Figure 5).

2009 Mark-Recapture

Mark-recapture population estimates were obtained at all sites and plot types for *Plethodon shermani*, all but Glade Branch control for *Desmognathus ocoee*, and only Glade Branch and Wine Springs controls for *Eurycea wilderae* (Table 2). Estimates included very wide 95% confidence intervals (Table 2, Figure 6) so no further analysis of the mark-recapture population estimates was performed. Hogan Branch was not included in analyses due to too few surveys. Capture probabilities did not differ significantly between plot types for *P. shermani* (T = 1.6804, df = 1, P = 0.1709), but were significantly lower in rhododendron for *D. ocoee* (T = 3.2132, df = 2, P = 0.04236, Table 2). For those sites and plot types where capture probabilities could be calculated, rhododendron plots typically had capture probabilities below 15%, with an average around 6% while non-rhododendron sites had higher capture probabilities with an average around 18% and a high of 46%.

Body condition did not differ significantly between rhododendron and non-rhododendron plots for *Plethodon shermani* (T = -0.3167, df = 3, P = 0.3861, Figure 7) or *Desmognathus ocoee* (T = 0.1949, df = 3, P = 0.429, Figure 8).

2010 Removal Sampling

The enclosures were successful in excluding previously marked salamanders. On any given night during removal surveys, no more than 5% of all salamanders captured had toe clips indicating they had been sampled previously. Removal sampling yielded population estimates for *Plethodon shermani* and *Desmognathus ocoee* at all site-plot type combinations except Glade Branch in the control for the latter, *Desmognathus wrighti* in both Deep Gap treatments, and *Eurycea wilderae* at Deep Gap in rhododendron and at Glade Branch in the control. All other species at all other site-plot type combinations did not have a sufficient number of individuals found for reliable population estimates (Table 3). The overall combined salamander population estimates pooled for all species did not vary significantly between plot types (T=-1.011, df=2, P=0.209, Figure 9). Similarly, overall biomass did not differ significantly amongst plot types for all species pooled (T = -1.687, df = 2, P = 0.117, Figure 10). While the estimates did not vary significantly, there is a slight trend in two of the three sites for more salamanders in the rhododendron (Figure 9).

The most common salamander species found at a given site varied. At Glade Branch and Hogan Branch, *P. shermani* was the most common species, while *D. ocoee* was the most common at Deep Gap (Table 3). Population estimates were highly variable for *D. ocoee* across sites and plot types, with Glade Control not having enough to get a reliable estimate and Deep Gap Rhododendron having more than 300, and as a result no analyses were run for this species using the 2010 data. *Plethodon shermani* estimates did not vary significantly between plot type for the population estimates (T=-1.357, df= 2, P = 0.154, Fig. 11) or for biomass (T = -1.394, df = 2, P = 0. 149, Fig 12). Again, while statistical tests were not significant, there is a slight trend for more *P. shermani* in rhododendron (Figure 11). There were not enough estimates to test any other species.

DISCUSSION

Although there were differences between rhododendron and non-rhododendron sites in habitat characteristics, rhododendron does not appear to significantly affect salamander population sizes or densities. There was generally much greater variability in salamander population estimates among sites than plot types, suggesting that any effect rhododendron has on salamander populations are lesser than the effect caused by the differences among my sites. There could be a number of reasons for this. One possibility is that rhododendron does not affect salamander population sizes and densities. The lack of body condition differences between plot types support this. Individual *P. shermani* and *D. ocoee* appeared to be equally robust in both rhododendron and non-rhododendron. Since body condition can be an indication of the ability of the salamanders to successfully forage, no detectable difference in body condition is suggestive that salamanders are equally able to find food in rhododendron and non-rhododendron areas. However, this does not mean that available prey does not differ between rhododendron and non-rhododendron sites, or that 2009 is representative of a typical year. It is possible that, because 2009 was an abnormally wet year (NOAA), salamanders may have had greater opportunities for forage, and thus were able to make up for any possible food deficits normally seen in either plot type.

It is also possible that food availability is less in rhododendron, but that shade and cooler temperatures under rhododendron canopies allow salamanders more opportunities to find food, making up for less available prey. There could be other unseen interactions that may hide any effects rhododendron may have on salamander populations. In addition, positive and negative effects caused by rhododendron could further be complicated by other factors, such as the surrounding forest type, aspect, and elevation. Deep Gap, the highest elevation of the sites and of a different hardwood forest type than the other two sites, showed less difference between plot types in percent plant cover and soil moisture than the other two sites (Figures 3 & 4). Deep Gap was also the site with the highest salamander densities. Interactions between rhododendron and other site characteristics may cause different effects on salamanders than rhododendron acting by itself. However, any interactive effects were beyond the scope of this study, and no net effects on salamanders were found through this study.

While no net effects on salamander population densities were found, the observed difference between control and rhododendron capture probabilities suggests that rhododendron does appear to influence the ability of a person to find salamanders within its thickets. Rhododendron can produce multiple stems and grows in a gnarly form, making it hard for a large animal like a human to move about. This inability to move freely throughout rhododendron thickets likely impacts a person’s ability to focus on finding salamanders and therefore reduces their search efficiency. If not properly accounted for, a reduction in the ability of a researcher to find salamanders under rhododendron canopies can impact the results of studies using abundance or other short term sampling techniques that do not estimate super population size or that do not take into account differences in detection capabilities between habitat types. Population studies should consider the potential influences of the environment on the search capabilities of the researchers and address issues of detection to ensure that population estimates are accurate and not reflective of biased search capabilities within the habitats surveyed.

Although they varied greatly among sites, most population density estimates, both for the total salamander community and for individual species, were much greater than those recorded in most other studies and areas in the Appalachians Mountains. My study sites yielded densities ranging from 1.57 salamanders/m^2 at Glade Branch to 7.32 salamanders/m^2 at Deep Gap. Other studies have found overall densities generally lower or at the low end of these estimates: 1.1 salamanders/m^2 in the Peaks of Otter region of Jefferson National Forest in Virginia (Kniowski & Reichenbacher 2009 for *Plethodon hubrichti* and *P. cinereus*), 0.51-1.84 salamanders/m^2 in the Black Mountains of North Carolina (Petranka & Murray 2001), 0.16-2.72 *Plethodon cinereus*/m^2 in New Hampshire (Burkes & Likens 1975), and 1.56-4.16 salamanders/m^2 in the Great Smoky Mountains (Bailey et al 2004b). *Plethodon shermani* estimates, which in this study ranged from 0.86/m^2 to 1.77/m^2,were comparable to other high elevation large *Plethodon* species such as *Plethodon montanus* (0.15/m^2) and *Plethodon yonahlossee* (0.07/m^2, Pentranka & Murray 2001) in the Black Mountains, and *Plethodon jordani*, *P. metcalfi*, and *Plethodon glutinosus* complex (0.18-1.43 salamanders/m^2, Bailey et al. 2004b) in the Great Smoky Mountains, but remained relatively higher than most. *Desmognathus ocoee* estimates were generally comparable to those found for *Desmognathus carolinensis*, a sister species found in a similar niche in the Black Mountains (1.07 salamanders/m^2, Petranka & Murray 2001), and but were markedly higher at Deep Gap (between 2.93 and 3.34 salamanders/m^2). Overall, the densities recorded at Deep Gap in this study represent some of the highest densities currently recorded for terrestrial salamanders in the world.

The Great Smoky Mountains study (Bailey et al. 2004b) came closest to yielding similar densities as those found at Deep Gap, and also compared a larger number of forest types and elevations. It is possible that elevations ranging between 1100-1300 meters in the Southern Appalachians, which were covered in the Great Smoky Mountains study and in this study, may contain the optimal for peak salamander densities in the region. Another possibility for my high densities is that the complex of salamander species present in the Nantahala Mountains, while being relatively similar to those found in studies conducted in nearby mountain ranges, interacts differently enough in such a way as to maximize their density compared to other salamander communities studies. For example, the Black Mountains have a second large *Plethodon*, *P. yonahlossee*, and the Great Smoky Mountains have more high elevation *Desmognathus* species, including *D. ocoee*, *D. imitator*, and *D. santeetlah* (Petranka 1998). These extra species, with counterparts not found in the Nantahala Mountains ,could increase competition among each species such that the overall capacity to hold high densities of salamanders is reduced at these locations.

However, the most likely explanation is that the close proximity of my study sites to low order streams and the occurrence of a higher than average rainfall in the year previous to when I determined population estimates (NOAA) may have caused a temporary inflation of salamander populations at my study sites. Approximately 66% of P. shermani and 55.8% of D. ocoee at Deep Gap were less than 25 mm SVL, making small and young individuals the large majority of the population for both species. These individuals, which likely were about one year old, may have better been able to survive in the higher rainfall from the previous year than usual, allowing for high populations in

2010. Salamanders are known to prefer moist conditions to forage, and smaller salamanders are more likely to desiccate or remain underground in dry condition (Spotila 1972; Fraser 1976; Grover 2000). A wet year would potentially allow for increased survivorship of young individuals by giving them more opportunities to forage and less risk of desiccation. Such increased survival of small individuals could account for the large numbers of small individuals seen in my study populations in 2010.

Interestingly, there was an unusually large number of *Eurycea wilderae* juveniles found in the Deep Gap rhododendron enclosures. Approximately 97% of the *E. wilderae* found in the Deep Gap rhododendron enclosures were less than 21mm SVL, with the average being 17.1mm SVL. It is possible that many of these individuals were unknowingly sealed into the enclosures when sites were prepared, or that their small nature allowed them to easily invade the enclosures. Since no other rhododendron sites had even remotely similar numbers, nor did the Deep Gap control, it is likely that the large numbers of *E. wilderae* juveniles found is not representative.

In conclusion, the upper Nantahala Mountains in western North Carolina are a productive area for salamanders. Terrestrial densities rival or surpass those found in most other studied locations, although higher than average rainfall may have inflated the estimates in this study. At least in the Nantahala Mountains, rhododendron does not appear to be a major factor in influencing salamander densities, although some effects may occur and could be further influenced by elevation, surrounding forest type, and other environmental factors.

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FIGURES AND TABLES

Table 1. Site information

Site Name	Year of Last Cut	Forest Type	Elevation (ft)	Years used	Slope	Aspect
Glade Branch	1928	yellow poplar	3484	2009-10		
Wine Springs	1900	white oak-red oak-hickory	4171	2009		
Hogan Branch	1930	yellow poplar-white oak-red oak	3557	2009-10		
Deep Gap	1927	sugar maple-beech-yellow birch	4235	2009-10		

Table 2. Population estimates, 95% confidence intervals, and capture probabilities from 2009 mark-recapture. An asterisk indicates the actual salamanders captured for that species at that plot type and site as a reliable population estimate could not be obtained.

Site	Plot Type	Species	Population Estimate	95% CI		Capture Probability		
				Lower	Upper	June	July	August
DeepGap	Control	*P. shermani*	210	115	768	NA	0.24	NA
Glade	Control	*P. shermani*	274	174	687	NA	NA	NA
Wine	Control	*P. shermani*	432	297	922	0.29	0.339	NA
DeepGap	Control	*D. ocoee*	181	105	950	NA	0.135	NA
Glade	Control	*D. ocoee*	5*	5	5	NA	0.203	NA
Wine	Control	*D. ocoee*	30	22	88	NA	0.204	NA
DeepGap	Rhodo	*P. shermani*	162	64	548	0.045	NA	NA
Glade	Rhodo	*P. shermani*	497	196	1562	0.514	0.16	NA
Wine	Rhodo	*P. shermani*	1273	294	6456	0.265	NA	NA
DeepGap	Rhodo	*D. ocoee*	249	94	1119	0.048	0.07	0.124
Glade	Rhodo	*D. ocoee*	45	27	134	0.128	0.07	0.056
Wine	Rhodo	*D. ocoee*	28	24	77	0.011	0.012	0.044

Table 3. Population estimates for each species and overall from 2010 removal sampling. Data pooled across enclosures and each plot type and site for this analysis. Zeroes indicate plot types and sites where no individuals of that species were found. An asterisk indicates the actual number of salamanders removed for that species at that plot type and site because reliable population estimates could not be obtained there.

	Deep Gap		Glade Branch		Hogan Branch	
Salamander Species	Control	Rhodo	Control	Rhodo	Control	Rhodo
Desmognathus aeneus	0	0	1*	3*	16*	5*
Desmognathus monicola	0	0	0	3*	0	0
Desmognathus ocoee	293	334	8*	65	145	67
Desmognathus wrighti	90	112	0	0	0	0
Eurycea wilderae	24*	149	26	9*	8*	2*
Gyrinophilus porphyriticus	0	2*	0	0	0	0
Plethodon shermani	86	135	131	174	176	177
Pseudotriton ruber	0	0	0	0	0	1*
Notophthalmus viridescens	0	0	0	0	0	0
Total	493	732	166	254	345	252

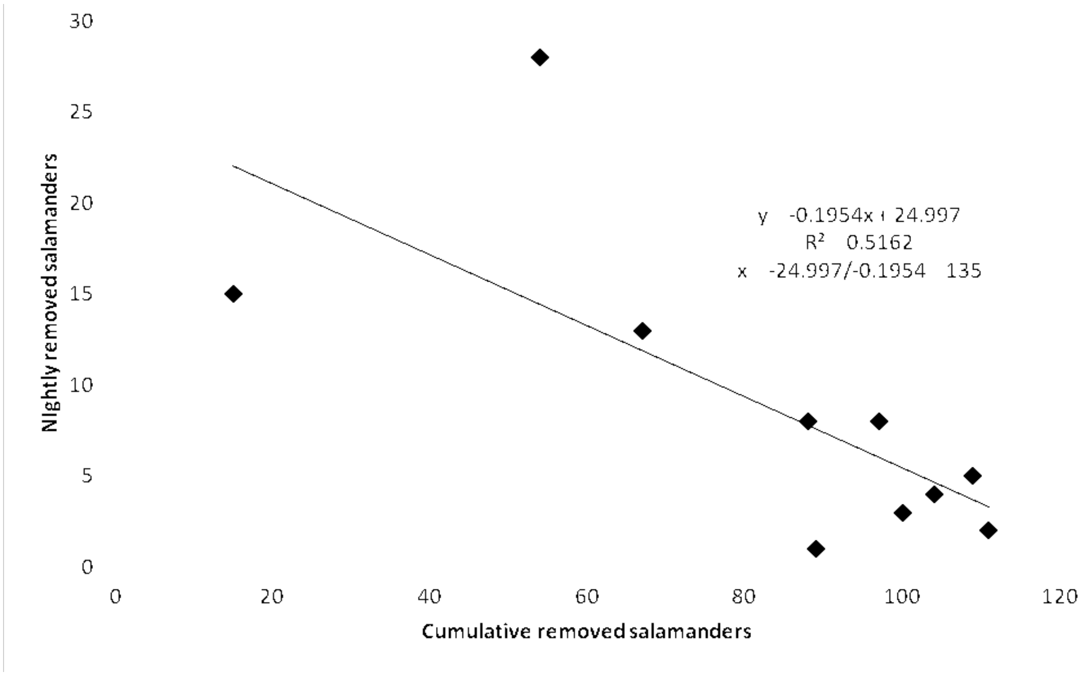

Figure 1. Sample Regression Used to Determine 2010 Removal Sampling Population Estimates

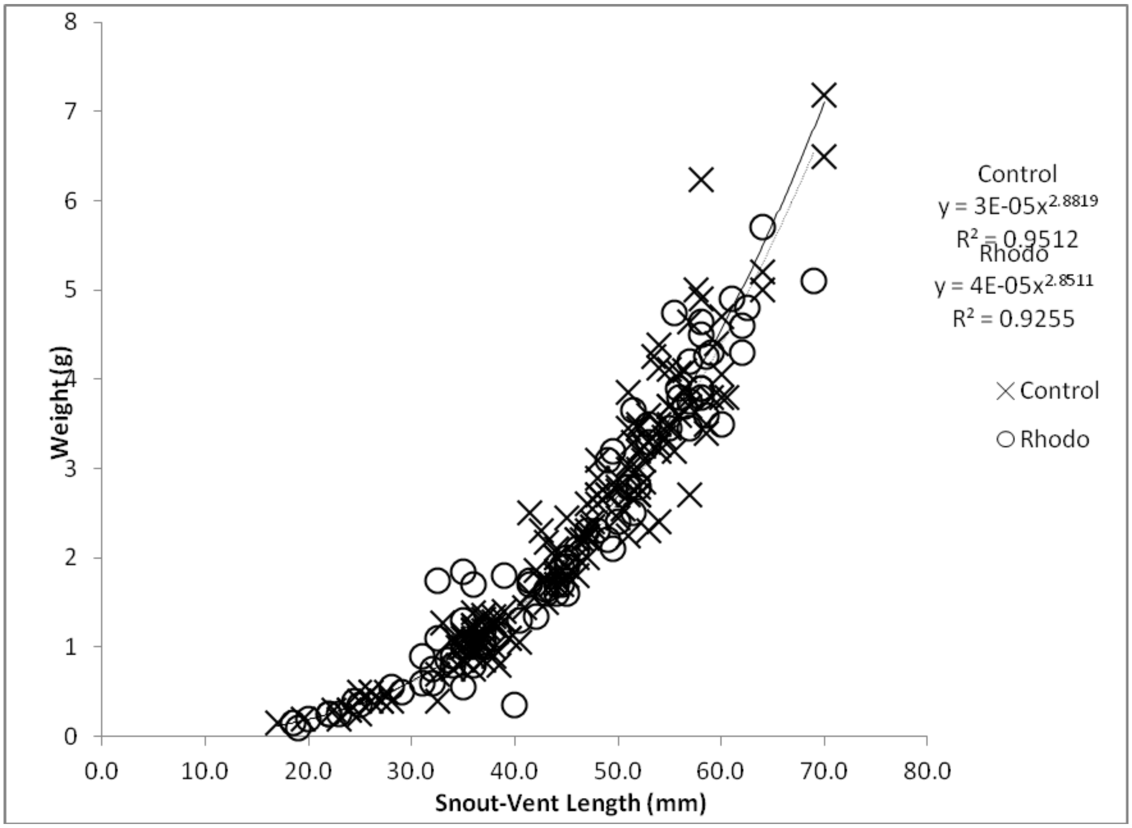

Figure 2. Regression of Snout-Vent Length and Mass for *Plethodon shermani* at one site for both rhododendron (O) and control (non-rhododendron, X) plots

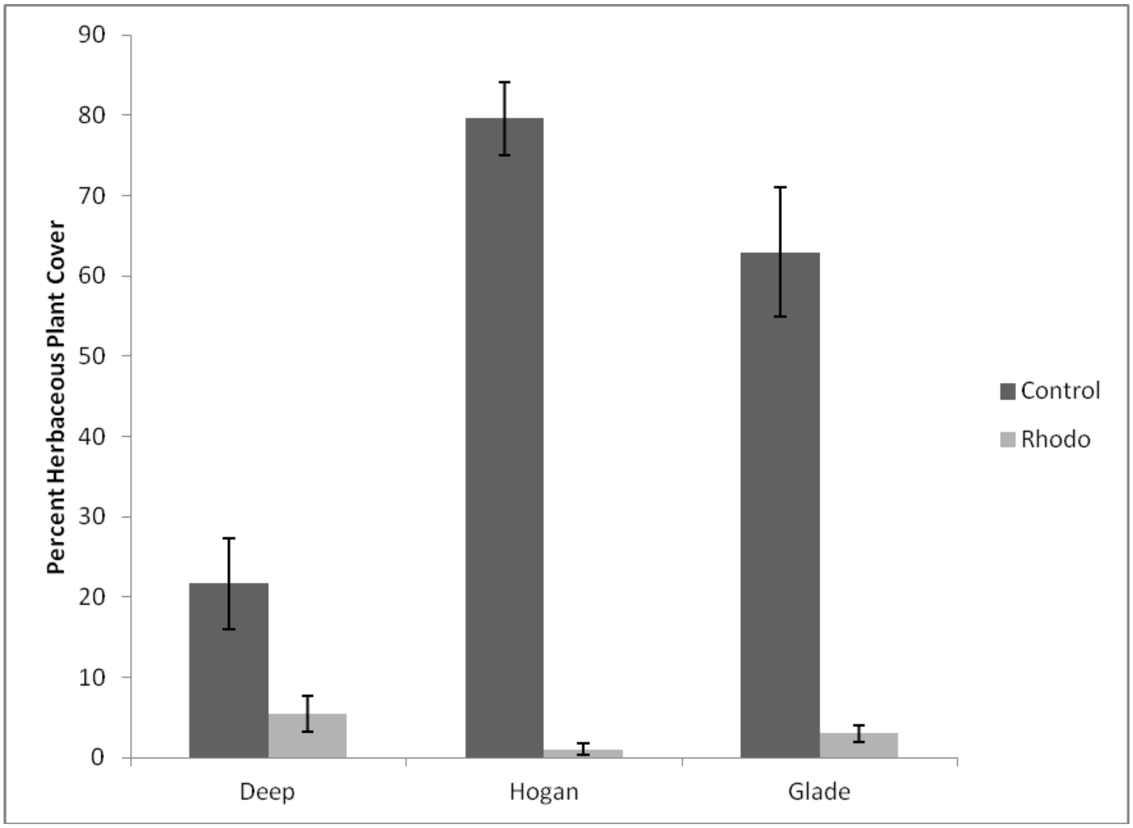

Figure 3. Average percent herbaceous plant cover for each site and treatment in 2010 with standard error

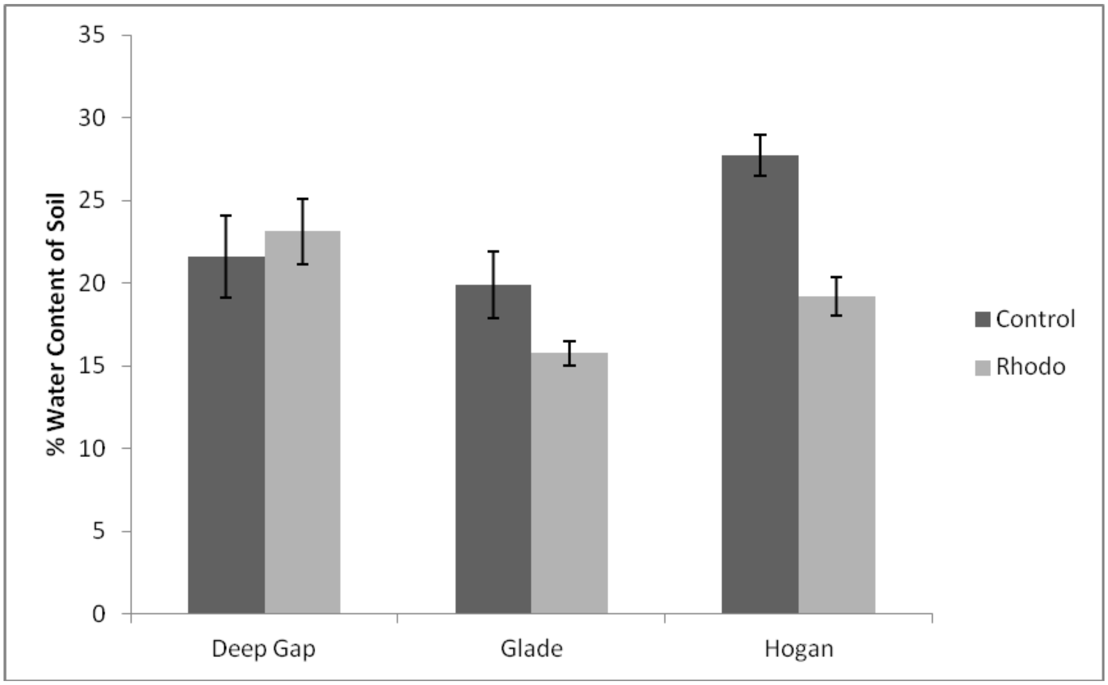

Figure 4. Average soil moisture for each site and treatment in 2010 with standard error

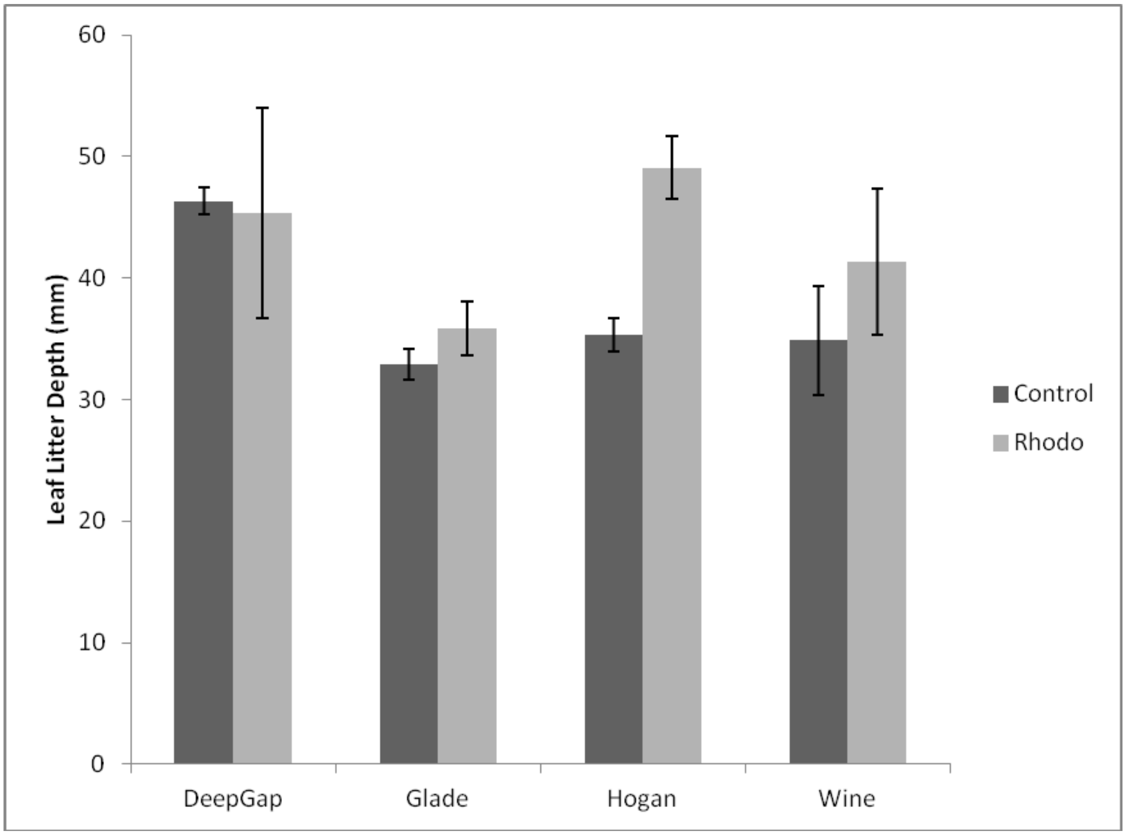

Figure 5. Average leaf litter depth collected in 2009 from the locations where individual salamanders were found, with standard error

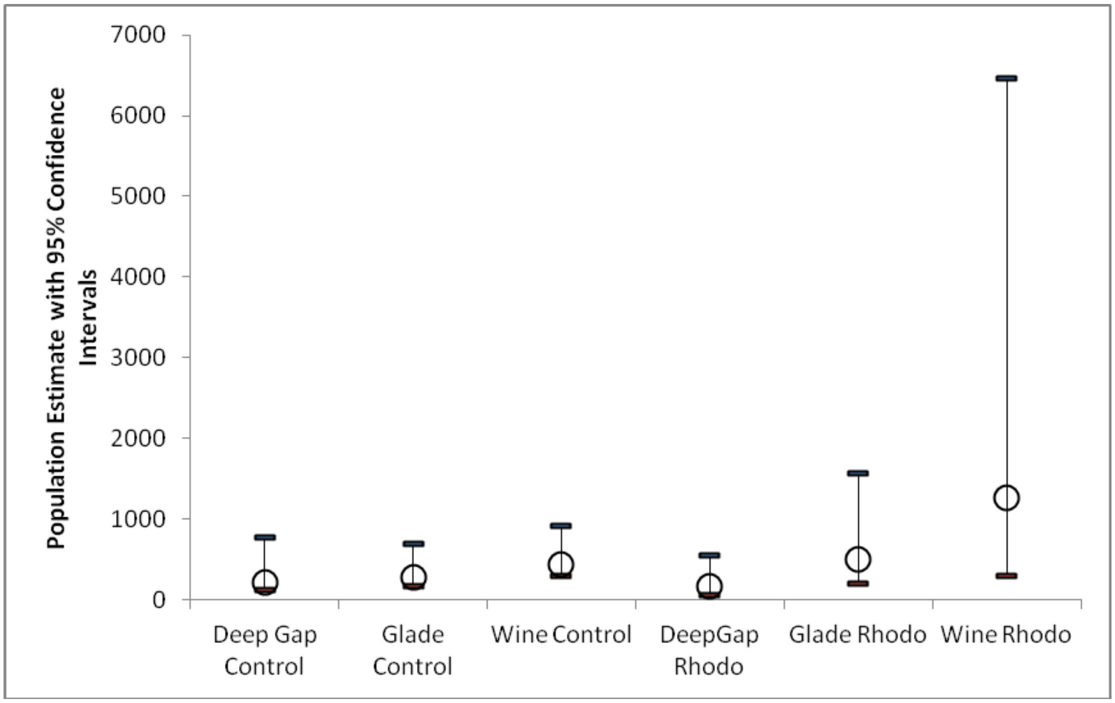

Figure 6. Population estimates from 2009 mark-recapture with 95% confidence intervals

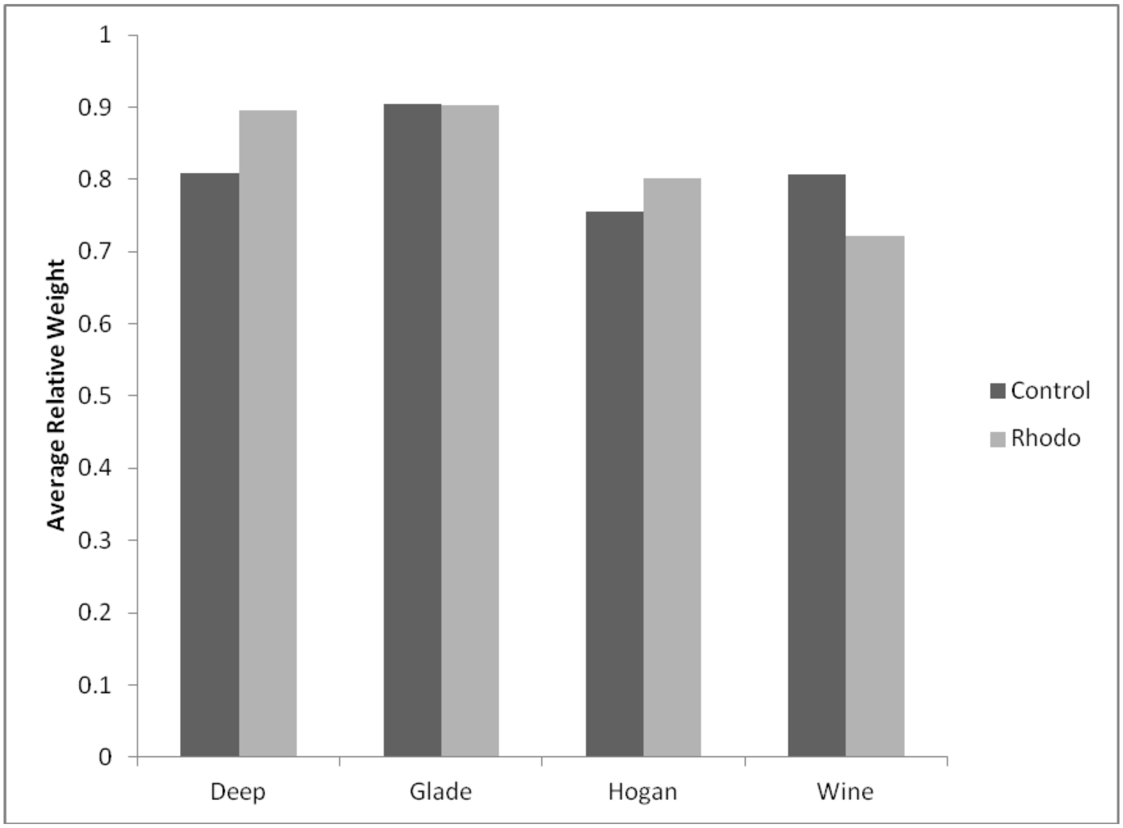

Figure 7. Average relative mass of *Plethodon shermani* in 2009

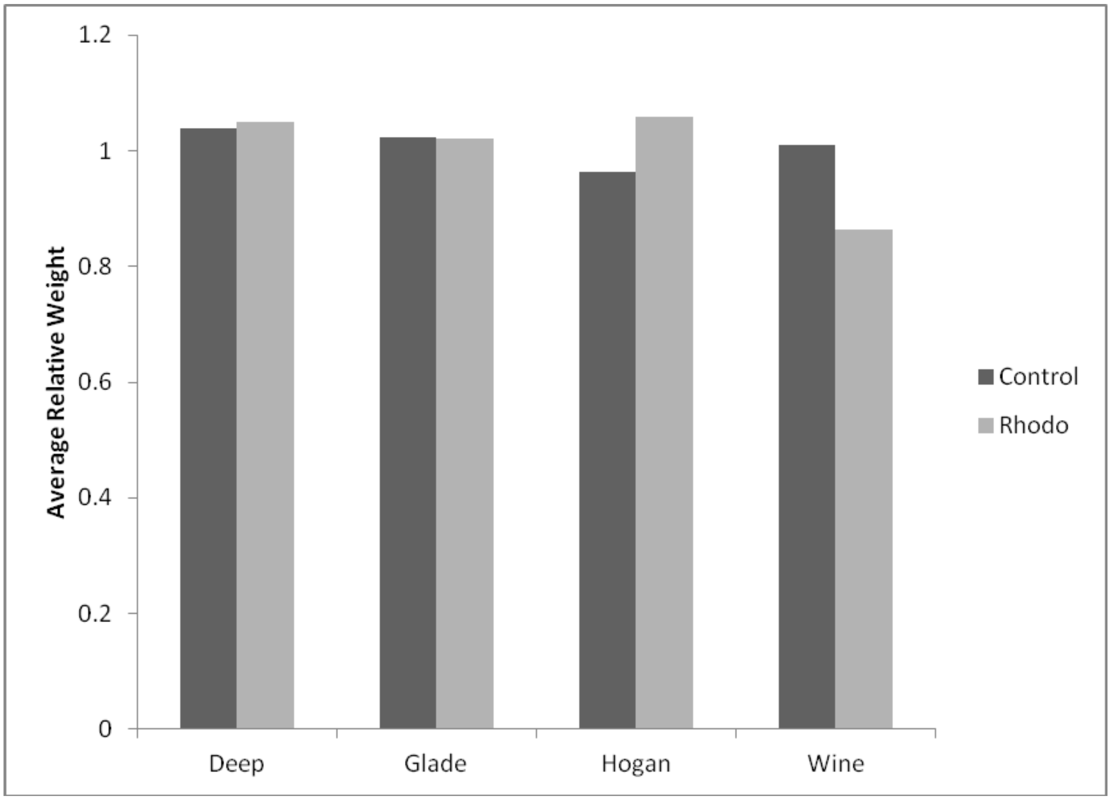

Figure 8. Average relative mass for *Desmognathus ocoee* in 2009

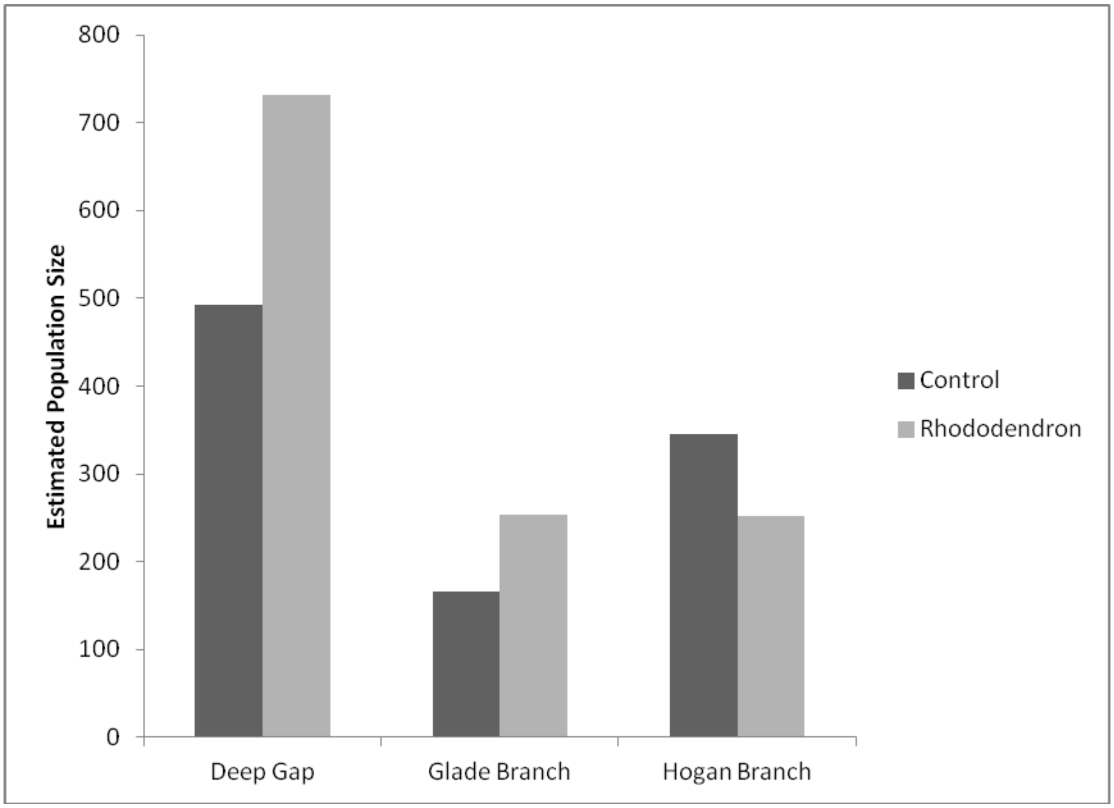

Figure 9. Overall population estimates pooled for all species from 2010 removal sampling

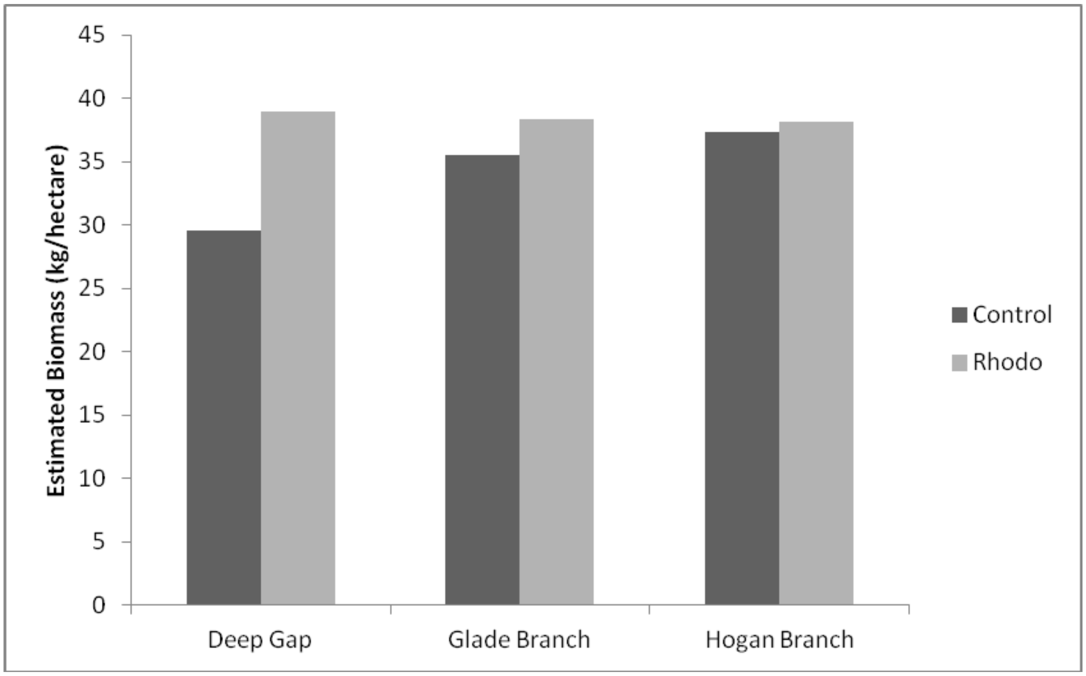

Figure 10. Overall biomass estimates pooled for all species possible and derived from 2010 population estimates

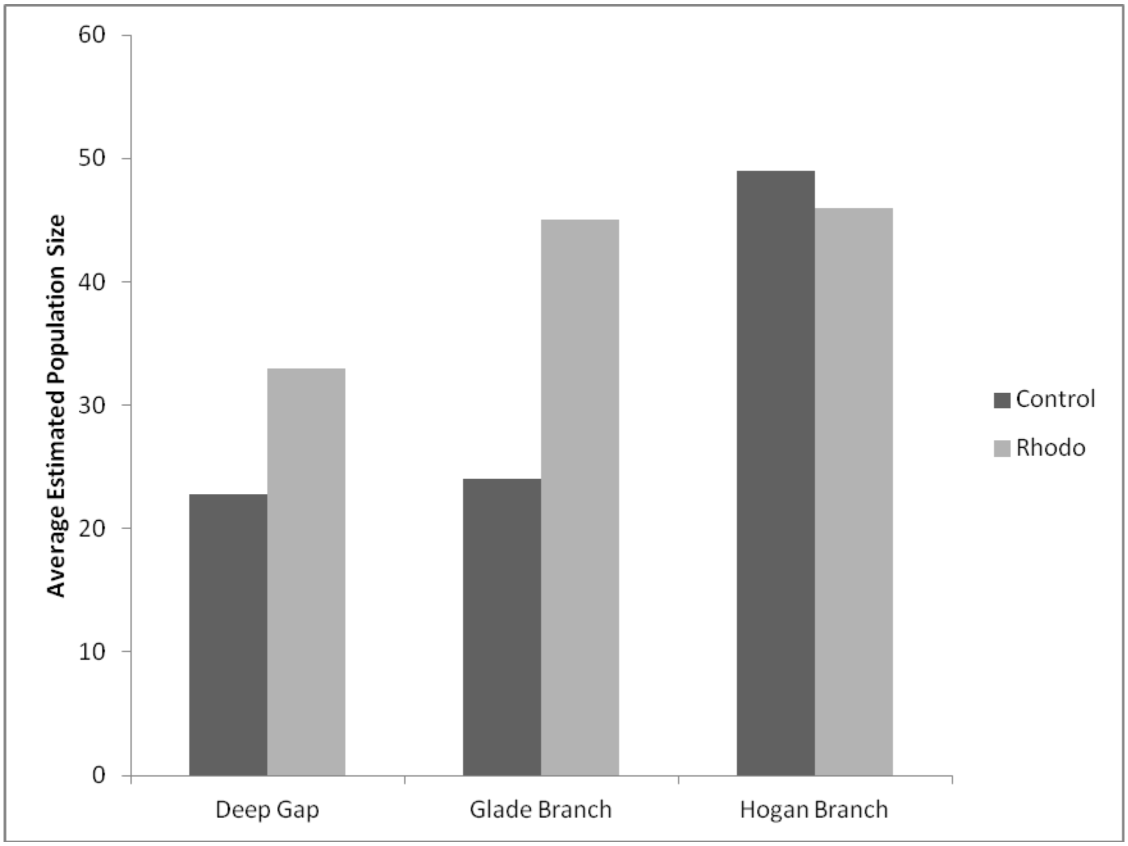

Figure 11. Average *Plethodon shermani* population estimates per enclosures for each site and plot type derived from 2010 Removal Surveys

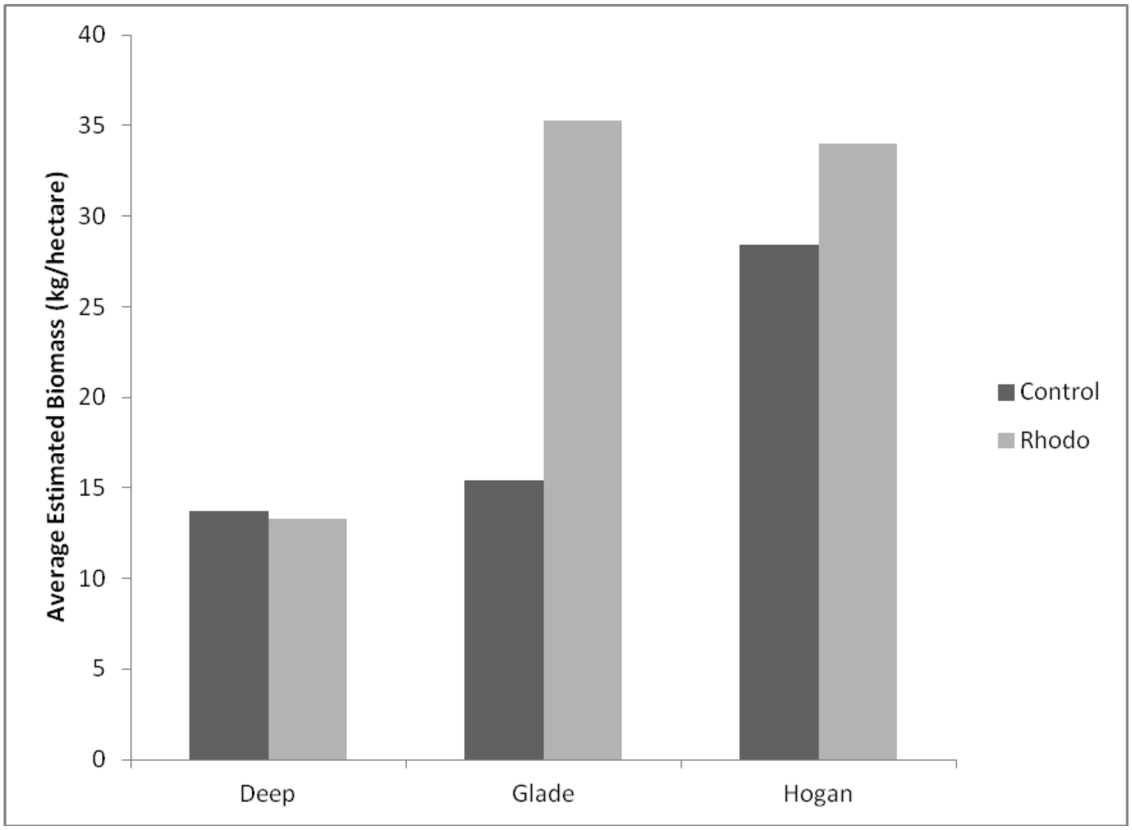

Figure 12. Average *Plethodon shermani* biomass estimates per enclosures for each site and plot type derived from 2010 population estimates

APPENDICES

Appendix 1. Population estimates for all species pooled at the enclosure level.

Site	Enclosure	Control	Rhodo
Deep	1	NA	NA
Deep	2	90	126
Deep	3	NA	159
Deep	4	186	243
Glade	1	NA	72
Glade	2	NA	NA
Glade	3	42	41
Glade	4	NA	NA
Hogan	1	79	67
Hogan	2	NA	72
Hogan	3	77	77
Hogan	4	NA	55

Appendix 2. *Plethodon shermani* population estimates for each enclosure.

Site	Enclosure	Control	Rhodo
Deep	1	26	27
Deep	2	20	24
Deep	3	26	48
Deep	4	19	NA
Glade	1	NA	64
Glade	2	NA	NA
Glade	3	24	26
Glade	4	NA	NA
Hogan	1	44	57
Hogan	2	54	37
Hogan	3	NA	NA
Hogan	4	NA	44

Appendix 3. Biomass estimates for the four major species for each site.

Species	Site	Biomass (kg/hectare)	
		Control	Rhododendron
Desmognathus ocoee	Deep Gap	14.37	20.37
	Glade Branch	NA	4.30
	Hogan Branch	11.80	5.45
Desmognathus wrighti	Deep Gap	1.84	2.92
Eurycea wilderae	Deep Gap	0.39	2.00
	Glade Branch	14.47	NA
Plethodon shermani	Deep Gap	12.93	13.61
	Glade Branch	21.08	34.06
	Hogan Branch	25.54	32.73

Appendix 4. *Plethodon shermani* biomass (kg/hectare) estimates for each enclosure.

Site	Plot	Control	Rhodo
Deep Gap	1	15.64	10.89
Deep Gap	2	12.03	9.68
Deep Gap	3	15.64	19.36
Deep Gap	4	11.43	NA
Glade Branch	1	NA	50.12
Glade Branch	2	NA	NA
Glade Branch	3	15.45	20.36
Glade Branch	4	NA	NA
Hogan Branch	1	25.54	42.16
Hogan Branch	2	31.34	27.37
Hogan Branch	3	NA	NA
Hogan Branch	4	NA	32.55

Appendix 5. Percent of ground cover plants collected in 2010 for each enclosure.

Site	Plot Type	Plot	Sample A	Sample B	Sample C	Ave % Cover
Deep	Control	1	15	50	45	36.67
Deep	Control	2	30	20	5	18.33
Deep	Control	3	10	15	5	10.00
Deep	Control	4	10	25	30	21.67
Deep	Rhodo	1	1	30	5	12.00
Deep	Rhodo	2	15	2	0	5.67
Deep	Rhodo	3	5	1	2	2.67
Deep	Rhodo	4	1	2	2	1.67
Hogan	Control	1	90	60	80	76.67
Hogan	Control	2	75	75	60	70.00
Hogan	Control	3	40	35	45	40.00
Hogan	Control	4	45	80	70	65.00
Hogan	Rhodo	1	0	0	10	3.33
Hogan	Rhodo	2	5	5	5	5.00
Hogan	Rhodo	3	0	0	1	0.33
Hogan	Rhodo	4	0	10	0	3.33
Glade	Control	1	85	80	95	86.67
Glade	Control	2	85	80	75	80.00
Glade	Control	3	95	70	90	85.00
Glade	Control	4	70	65	65	66.67
Glade	Rhodo	1	1	0	1	0.67
Glade	Rhodo	2	0	5	5	3.33
Glade	Rhodo	3	0	0	0	0.00
Glade	Rhodo	4	0	0	0	0.00

Appendix 6. Soil moisture as measured by a TDR data collected in 2010 for each site and plot type during salamander removal surveys.

Date	Site	Plot Type	Condition	Plot	M1	M2	M3	M4	M5	Ave
7/5/2010	Deep	Control	Dry	1	15.2	32.6	18.1	16.3	12.3	18.9
7/5/2010	Deep	Control	Dry	2	30.4	24.3	11.6	17.0	27.9	22.2
7/5/2010	Deep	Control	Dry	3	23.2	13.1	6.6	26.1	16.0	17.0
7/5/2010	Deep	Control	Dry	4	22.1	16.3	32.6	29.3	36.6	27.4
7/7/2010	Deep	Control	Dry	1	9.1	13.1	7.6	18.1	16.0	12.8
7/7/2010	Deep	Control	Dry	2	20.7	9.1	18.1	13.8	12.0	14.7
7/7/2010	Deep	Control	Dry	3	21.4	10.5	14.5	21.0	30.4	19.6
7/7/2010	Deep	Control	Dry	4	37.7	39.8	28.6	33.0	21.0	32.0
7/10/2010	Deep	Control	Damp	1	21.0	6.9	8.0	24.6	19.6	16.0
7/10/2010	Deep	Control	Damp	2	17.8	16.0	8.4	15.6	21.4	15.8
7/10/2010	Deep	Control	Damp	3	25.0	19.9	5.1	12.3	12.3	14.9
7/10/2010	Deep	Control	Damp	4	13.1	22.5	40.2	27.9	29.0	26.5
7/15/2010	Deep	Control	Dry	1	27.2	32.2	20.7	8.0	26.1	22.8
7/15/2010	Deep	Control	Dry	2	34.0	16.0	26.4	15.2	22.5	22.8
7/15/2010	Deep	Control	Dry	3	29.0	28.3	31.9	12.3	19.6	24.2
7/15/2010	Deep	Control	Dry	4	26.4	23.2	25.4	34.4	35.5	29.0
7/19/2010	Deep	Control	Damp	1	14.5	31.5	17.0	24.6	17.8	21.1
7/19/2010	Deep	Control	Damp	2	21.6	23.9	17.4	11.6	26.4	20.2
7/19/2010	Deep	Control	Damp	3	11.3	21.0	15.2	29.0	28.6	21.0
7/19/2010	Deep	Control	Damp	4	31.1	27.9	34.0	29.7	31.1	30.8
7/22/2010	Deep	Control	Wet	1	9.5	25.6	25.7	18.9	13.8	18.7
7/22/2010	Deep	Control	Wet	2	11.6	26.1	21.0	10.9	11.6	16.2
7/22/2010	Deep	Control	Wet	3	31.5	27.5	20.3	27.2	24.3	26.2
7/22/2010	Deep	Control	Wet	4	31.9	26.1	16.0	33.7	27.2	27.0
7/5/2010	Deep	Rhodo	Dry	1	20.6	19.9	19.2	15.6	10.9	17.2
7/5/2010	Deep	Rhodo	Dry	2	17.8	19.9	9.5	27.9	18.9	18.8
7/5/2010	Deep	Rhodo	Dry	3	18.9	15.8	18.5	30.1	23.2	21.3
7/5/2010	Deep	Rhodo	Dry	4	17.7	16.9	13.1	29.7	32.2	21.9
7/7/2010	Deep	Rhodo	Dry	1	13.8	16.3	16.0	27.5	22.8	19.3
7/7/2010	Deep	Rhodo	Dry	2	16.3	23.6	11.6	9.5	20.7	16.3
7/7/2010	Deep	Rhodo	Dry	3	25.7	38.4	17.8	26.8	30.8	27.9
7/7/2010	Deep	Rhodo	Dry	4	28.3	24.6	5.8	28.6	12.7	20.0
7/10/2010	Deep	Rhodo	Damp	1	9.1	24.6	22.1	21.0	13.4	18.0
7/10/2010	Deep	Rhodo	Damp	2	12.3	13.4	16.3	22.5	21.4	17.2
7/10/2010	Deep	Rhodo	Damp	3	42.7	23.6	23.9	27.9	12.3	26.1
7/10/2010	Deep	Rhodo	Damp	4	27.2	23.2	20.3	14.9	22.5	21.6
7/15/2010	Deep	Rhodo	Dry	1	16.7	27.2	22.8	29.0	10.9	21.3
7/15/2010	Deep	Rhodo	Dry	2	30.1	15.6	11.6	25.4	19.6	20.5
7/15/2010	Deep	Rhodo	Dry	3	48.5	17.4	26.8	34.8	10.5	27.6

7/15/2010	Deep	Rhodo	Dry	4	36.2	28.3	30.1	23.9	26.8	29.1
7/19/2010	Deep	Rhodo	Damp	1	12.7	21.0	33.7	12.7	9.5	17.9
7/19/2010	Deep	Rhodo	Damp	2	29.3	22.5	20.3	26.4	15.2	22.7
7/19/2010	Deep	Rhodo	Damp	3	32.6	53.9	13.1	36.9	17.8	30.9
7/19/2010	Deep	Rhodo	Damp	4	29.0	28.2	19.6	29.3	33.7	28.0
7/22/2010	Deep	Rhodo	Wet	1	23.6	9.5	23.9	25.7	14.2	19.4
7/22/2010	Deep	Rhodo	Wet	2	26.4	23.9	40.2	21.0	33.7	29.0
7/22/2010	Deep	Rhodo	Wet	3	32.6	37.3	44.9	27.5	11.3	30.7
7/22/2010	Deep	Rhodo	Wet	4	32.6	35.1	22.1	34.8	35.5	32.0
7/5/2010	Glade	Control	Dry	1	17.4	25.4	21.0	28.3	23.6	23.1
7/5/2010	Glade	Control	Dry	2	18.9	13.1	26.1	29.3	26.1	22.7
7/5/2010	Glade	Control	Dry	3	20.3	25.7	16.3	29.7	20.7	22.5
7/5/2010	Glade	Control	Dry	4	20.7	14.9	11.2	10.8	15.6	14.6
7/7/2010	Glade	Control	Dry	1	28.3	13.8	20.9	19.4	21.0	20.7
7/7/2010	Glade	Control	Dry	2	12.0	10.2	25.4	20.3	23.2	18.2
7/7/2010	Glade	Control	Dry	3	18.1	18.9	17.4	24.6	23.9	20.6
7/7/2010	Glade	Control	Dry	4	14.5	3.3	13.1	4.0	11.3	9.2
7/15/2010	Glade	Control	Dry	1	16.7	10.9	20.3	20.3	32.6	20.2
7/15/2010	Glade	Control	Dry	2	10.5	19.6	21.3	12.3	21.7	17.1
7/15/2010	Glade	Control	Dry	3	17.8	18.5	21.7	18.5	12.3	17.8
7/15/2010	Glade	Control	Dry	4	12.3	12.7	15.2	6.0	18.9	13.0
9/12/2010	Glade	Control	Damp	1	23.9	27.2	29.3	20.3	18.9	23.9
9/12/2010	Glade	Control	Damp	2	19.2	36.6	25.4	29.0	31.1	28.3
9/12/2010	Glade	Control	Damp	3	31.1	23.2	23.9	32.1	29.7	28.0
9/12/2010	Glade	Control	Damp	4	22.1	11.3	19.6	25.4	14.9	18.7
7/5/2010	Glade	Rhodo	Dry	1	13.8	10.2	13.4	12.0	12.0	12.3
7/5/2010	Glade	Rhodo	Dry	2	10.9	4.0	8.4	5.1	22.5	10.2
7/5/2010	Glade	Rhodo	Dry	3	10.2	11.8	3.3	10.5	16.3	10.4
7/5/2010	Glade	Rhodo	Dry	4	13.8	9.5	13.7	12.1	21.0	14.0
7/7/2010	Glade	Rhodo	Dry	1	14.2	16.7	12.3	13.1	11.6	13.6
7/7/2010	Glade	Rhodo	Dry	2	17.4	11.3	18.5	12.0	5.5	12.9
7/7/2010	Glade	Rhodo	Dry	3	26.8	4.8	6.6	4.8	8.4	10.3
7/7/2010	Glade	Rhodo	Dry	4	13.4	9.5	11.6	17.0	19.9	14.3
7/15/2010	Glade	Rhodo	Dry	1	16.7	19.2	11.6	15.6	18.5	16.3
7/15/2010	Glade	Rhodo	Dry	2	19.2	18.9	11.6	20.7	25.0	19.1
7/15/2010	Glade	Rhodo	Dry	3	13.8	23.2	14.9	21.0	17.0	18.0
7/15/2010	Glade	Rhodo	Dry	4	17.4	25.7	14.9	27.2	12.0	19.4
9/12/2010	Glade	Rhodo	Damp	1	19.2	9.8	16.3	9.8	8.7	12.8
9/12/2010	Glade	Rhodo	Damp	2	28.3	34.4	27.9	4.0	21.7	23.3
9/12/2010	Glade	Rhodo	Damp	3	39.1	19.2	26.8	26.1	12.7	24.8
9/12/2010	Glade	Rhodo	Damp	4	16.7	16.0	28.5	27.2	14.2	20.5
7/7/2010	Hogan	Control	Dry	1	16.0	16.7	26.1	17.8	19.2	19.2

7/7/2010	Hogan	Control	Dry	2	14.2	34.8	5.8	25.4	30.4	22.1
7/7/2010	Hogan	Control	Dry	3	30.1	27.3	30.4	21.7	28.3	27.6
7/7/2010	Hogan	Control	Dry	4	30.1	11.6	18.9	30.1	25.0	23.1
7/8/2010	Hogan	Control	Dry	1	26.1	16.3	13.8	8.0	27.5	18.3
7/8/2010	Hogan	Control	Dry	2	20.7	27.5	19.9	18.1	23.6	22.0
7/8/2010	Hogan	Control	Dry	3	31.9	30.4	21.0	22.5	17.8	24.7
7/8/2010	Hogan	Control	Dry	4	24.6	19.2	23.9	20.7	25.0	22.7
7/19/2010	Hogan	Control	Damp	1	18.9	24.6	30.4	31.1	29.7	26.9
7/19/2010	Hogan	Control	Damp	2	34.4	29.7	23.2	21.0	34.0	28.5
7/19/2010	Hogan	Control	Damp	3	39.1	30.4	41.3	35.8	33.3	36.0
7/19/2010	Hogan	Control	Damp	4	34.4	25.7	22.5	29.3	29.7	28.3
7/22/2010	Hogan	Control	Wet	1	30.8	29.3	34.0	24.3	30.4	29.8
7/22/2010	Hogan	Control	Wet	2	33.0	36.2	33.0	42.0	29.7	34.8
7/22/2010	Hogan	Control	Wet	3	38.4	26.1	41.6	27.9	29.0	32.6
7/22/2010	Hogan	Control	Wet	4	26.8	35.5	36.2	37.7	33.3	33.9
9/12/2010	Hogan	Control	Damp	1	34.8	25.0	31.1	26.8	34.4	30.4
9/12/2010	Hogan	Control	Damp	2	36.4	21.4	34.8	34.0	28.6	31.0
9/12/2010	Hogan	Control	Damp	3	36.2	30.1	38.4	35.5	30.8	34.2
9/12/2010	Hogan	Control	Damp	4	33.3	20.7	32.2	31.9	23.6	28.3
7/7/2010	Hogan	Rhodo	Dry	1	20.7	21.0	19.2	4.8	16.7	16.5
7/7/2010	Hogan	Rhodo	Dry	2	17.4	10.9	15.6	21.0	10.2	15.0
7/7/2010	Hogan	Rhodo	Dry	3	14.9	18.9	24.3	29.3	20.7	21.6
7/7/2010	Hogan	Rhodo	Dry	4	4.0	5.8	12.0	14.2	28.3	12.9
7/8/2010	Hogan	Rhodo	Dry	1	16.0	21.0	4.8	10.9	21.7	14.9
7/8/2010	Hogan	Rhodo	Dry	2	12.3	19.6	10.2	6.9	10.9	12.0
7/8/2010	Hogan	Rhodo	Dry	3	13.8	9.8	25.7	25.4	18.5	18.6
7/8/2010	Hogan	Rhodo	Dry	4	8.0	15.2	5.8	23.2	11.3	12.7
7/19/2010	Hogan	Rhodo	Damp	1	26.1	28.3	9.8	12.7	12.3	17.8
7/19/2010	Hogan	Rhodo	Damp	2	17.8	17.4	14.9	7.3	13.4	14.2
7/19/2010	Hogan	Rhodo	Damp	3	17.8	13.1	15.6	22.1	24.6	18.6
7/19/2010	Hogan	Rhodo	Damp	4	13.4	19.6	19.9	17.4	18.9	17.8
7/22/2010	Hogan	Rhodo	Wet	1	33.0	12.0	21.0	18.1	25.4	21.9
7/22/2010	Hogan	Rhodo	Wet	2	26.8	22.5	38.4	19.9	24.6	26.4
7/22/2010	Hogan	Rhodo	Wet	3	24.3	33.0	34.8	40.5	14.9	29.5
7/22/2010	Hogan	Rhodo	Wet	4	32.6	18.5	32.6	30.1	29.7	28.7
9/12/2010	Hogan	Rhodo	Damp	1	17.4	14.9	11.6	27.2	24.3	19.1
9/12/2010	Hogan	Rhodo	Damp	2	25.0	15.6	18.9	31.1	20.7	22.3
9/12/2010	Hogan	Rhodo	Damp	3	22.5	16.3	27.9	27.9	28.3	24.6
9/12/2010	Hogan	Rhodo	Damp	4	19.9	19.6	21.7	12.0	20.3	18.7

Appendix 7. Arthropod data collected from three 1m^2 leaf litter samples at each study plot in 2009. Samples were extracted with a Berlese funnel and the number of individuals of each order counted. This data was ultimately not used in this thesis but is included here in case anyone in the future wishes to use it. Counts were aided by Sarah Hribar.

Site	Treatment	Order	Individuals
Glade	Control	Coleoptera	40
Glade	Control	Hymenoptera	48
Glade	Control	Pseudoscorpiones	14
Glade	Control	Spiders	16
Glade	Control	Nematodes	14
Glade	Control	Centipedes	22
Glade	Control	Millpedes	13
Glade	Control	Molluska	2
Glade	Control	Collembola	188
Glade	Control	Acari	856
Glade	Control	Diptera	0
Glade	Control	Hemiptera	1
Glade	Control	Amdida	0
Glade	Control	Symphylla	0
Glade	Control	Protura	0
Glade	Control	Isopoda	0
Glade	Control	Diplura	0
Glade	Control	Opilliones	0
Glade	Control	Oligochaetes	0
Glade	Control	Unidentified	51
Glade	Rhodo	Coleoptera	13
Glade	Rhodo	Hymenoptera	28
Glade	Rhodo	Pseudoscorpiones	14
Glade	Rhodo	Spiders	4
Glade	Rhodo	Nematodes	0
Glade	Rhodo	Centipedes	3
Glade	Rhodo	Millipedes	23
Glade	Rhodo	Molluska	0
Glade	Rhodo	collembola	44
Glade	Rhodo	Acari	226
Glade	Rhodo	Diptera	0
Glade	Rhodo	Hemiptera	0
Glade	Rhodo	Amdida	0
Glade	Rhodo	Symphylla	5
Glade	Rhodo	Protura	0
Glade	Rhodo	Isopoda	0
Glade	Rhodo	Diplura	0
Glade	Rhodo	Opilliones	0
Glade	Rhodo	Oligochaetes	0
Glade	Rhodo	Unidentified	16
WineSprings	Control	Coleoptera	58
WineSprings	Control	Hymenoptera	13
WineSprings	Control	Pseudoscorpiones	4
WineSprings	Control	Spiders	9

WineSprings	Control	Nematodes	0
WineSprings	Control	Centipedes	12
WineSprings	Control	Millipedes	17
WineSprings	Control	Molluska	0
WineSprings	Control	Collembola	273
WineSprings	Control	Acari	926
WineSprings	Control	Diptera	1
WineSprings	Control	Hemiptera	0
WineSprings	Control	Amdida	0
WineSprings	Control	Symphylla	1
WineSprings	Control	Protura	4
WineSprings	Control	Isopoda	1
WineSprings	Control	Diplura	0
WineSprings	Control	Opilliones	0
WineSprings	Control	Unidentified	31
WineSprings	Rhodo	Coleoptera	100
WineSprings	Rhodo	Hymenoptera	41
WineSprings	Rhodo	Pseudoscorpiones	16
WineSprings	Rhodo	Spiders	8
WineSprings	Rhodo	Nematodes	0
WineSprings	Rhodo	Centipedes	6
WineSprings	Rhodo	Millipedes	43
WineSprings	Rhodo	Molluska	2
WineSprings	Rhodo	Collembola	163
WineSprings	Rhodo	Acari	706
WineSprings	Rhodo	Diptera	17
WineSprings	Rhodo	Hemiptera	1
WineSprings	Rhodo	Amdida	8
WineSprings	Rhodo	Symphylla	1
WineSprings	Rhodo	Protura	1
WineSprings	Rhodo	Isopoda	0
WineSprings	Rhodo	Diplura	2
WineSprings	Rhodo	Opiliones	5
WineSprings	Rhodo	Oligochaetes	0
WineSprings	Rhodo	Unidentified	20
DeepGap	Control	Coleoptera	10
DeepGap	Control	Hymenoptera	6
DeepGap	Control	Pseudoscorpiones	7
DeepGap	Control	Spiders	3
DeepGap	Control	Nematodes	0
DeepGap	Control	Centipedes	4
DeepGap	Control	Millipedes	13
DeepGap	Control	Molluska	0
DeepGap	Control	Collembola	7
DeepGap	Control	Acari	425
DeepGap	Control	Diptera	8
DeepGap	Control	Hemiptera	0
DeepGap	Control	Amdida	0
DeepGap	Control	Symphylla	0
DeepGap	Control	Protura	3

DeepGap	Control	Isopoda	1
DeepGap	Control	Diplura	0
DeepGap	Control	Opilliones	0
DeepGap	Control	Oligochaetes	2
DeepGap	Control	Unidentified	0
DeepGap	Rhodo	Coleoptera	12
DeepGap	Rhodo	Hymenoptera	11
DeepGap	Rhodo	Pseudoscorpiones	4
DeepGap	Rhodo	Spiders	24
DeepGap	Rhodo	Nematodes	2
DeepGap	Rhodo	Centipedes	3
DeepGap	Rhodo	Millipedes	2
DeepGap	Rhodo	Molluska	1
DeepGap	Rhodo	Collembola	51
DeepGap	Rhodo	Acari	209
DeepGap	Rhodo	Diptera	0
DeepGap	Rhodo	Hemiptera	0
DeepGap	Rhodo	Amdida	0
DeepGap	Rhodo	Symphylla	0
DeepGap	Rhodo	Protura	1
DeepGap	Rhodo	Isopoda	0
DeepGap	Rhodo	Diplura	0
DeepGap	Rhodo	Opilliones	0
DeepGap	Rhodo	Oligochaetes	1
DeepGap	Rhodo	Unidentified	21
Hogan	Control	Coleoptera	0
Hogan	Control	Hymenoptera	28
Hogan	Control	Pseudoscorpions	6
Hogan	Control	Spiders	13
Hogan	Control	Nematodes	0
Hogan	Control	Centipedes	4
Hogan	Control	Millpedes	3
Hogan	Control	Molluska	3
Hogan	Control	Collembola	87
Hogan	Control	Acari	145
Hogan	Control	Diptera	1
Hogan	Control	Hemiptera	3
Hogan	Control	Amdida	0
Hogan	Control	Symphylla	2
Hogan	Control	Protura	3
Hogan	Control	Isopoda	0
Hogan	Control	Diplura	0
Hogan	Control	Opilliones	0
Hogan	Control	Oligochaetes	8
Hogan	Control	Unidentified	22
Hogan	Rhodo	Coleoptera	3
Hogan	Rhodo	Hymenoptera	14
Hogan	Rhodo	Pseudoscorpions	3
Hogan	Rhodo	Spiders	25
Hogan	Rhodo	Nematodes	0

Hogan	Rhodo	Centipedes	3
Hogan	Rhodo	Millpedes	11
Hogan	Rhodo	Molluska	5
Hogan	Rhodo	Collembola	70
Hogan	Rhodo	Acari	212
Hogan	Rhodo	Diptera	5
Hogan	Rhodo	Hemiptera	1
Hogan	Rhodo	Amdida	0
Hogan	Rhodo	Symphylla	9
Hogan	Rhodo	Protura	0
Hogan	Rhodo	Isopoda	0
Hogan	Rhodo	Diplura	1
Hogan	Rhodo	Opilliones	1
Hogan	Rhodo	Oligochaetes	4
Hogan	Rhodo	Unidentified	24