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DEPARTMENT OF ECOSYSTEM SCIENCE AND MANAGEMENT

THE EFFECTS OF A PRAIRIE GRASS RESTORATION ON SMALL MAMMAL POPULATIONS IN THE PENNSYLVANIA STATE UNIVERSITY ARBORETUM

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ABSTRACT

Prairie grassland conservation is an important management issue in the restoration of historical habitats in Pennsylvania. To determine how small mammals are being affected by an ongoing prairie grass restoration at the Pennsylvania State Arboretum I conducted a live trapping mark-recapture study throughout the months of June-August 2012. The current treatment area is a 2.02 hectare grassland that has a mix of prairie grasses and invasive species as compared with a nearby control site that was dominated by invasive shrubs and grass species. I had several hypotheses for this experiment all of which focused on how restoration efforts would affect small mammal composition and community structure. Most species expected in the treatment area included meadow voles (*Microtus pennsylvanicus*), deer mice (*Peromyscus maniculatus*), white-footed mice (*Peromyscus leucopus*) and red-backed voles (*Myodes gapperi*). While there were a few significant differences in relative abundance and relative density on the species level, the community level did not show prominent differences in these measures. Estimated population size showed little difference between the treatment and the control sites, but only with one species, demonstrating little significance within the community. The treatment area had a lower diversity index but a higher evenness value as compared with the control area. Overall there was no significant difference in relative abundance estimated population size or relative density as this was the first year of the study since the original restoration efforts in 2001 and there were few changes between the treatment and control sites. This experiment will assist in continuing restoration efforts and be used in future research as baseline study for small mammal species composition in other prairie grass restoration sites in Pennsylvania.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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INTRODUCTION

Prior to European settlement in many parts of what is now the United States there was a variety of open prairie grasslands that sustained specialized communities of plant and animal life (Laughlin 2002). During European settlement many of these grasslands were degraded and destroyed by agriculture, residential development and burning (Laughlin 2002). Today there are many areas throughout the world that are struggling with sustaining or regenerating prairie grasslands (Laughlin 2002). Many states in the US are having difficulty with conserving and restoring these grasslands, specifically those in the Midwest. The current issues faced in these areas are invasive species overtaking what is left of the native grasslands and changing the habitat even more from its original form (Ruffner and McCulley 2012)

In Pennsylvania, USA grasslands were present in the central regions of the state (Lawless et al. 2006). However, many of the same issues such as agriculture and residential development fragmented or destroyed many of these prairie grasslands. Woody plant invasion was another issue that overtook prairies in Pennsylvania (Lawless et al. 2006). Over the last 50 years Pennsylvania has seen a reduction in grasslands by 78% in the Ridge and Valley region and 92% in the Westfall Ridge region (Laughlin 2002). Invasive species, such as privet (*Ligustrum obtusifolium*), have invaded and out-competed native species, which has led to the further reduction in grassland species in Pennsylvania (Laughlin 2002).

There are two different types of prairie grasslands in the United States: tall-grass and short-grass. It is believed that mesic tall grasses never extended into Pennsylvania (Laughlin 2002). Tall-grass prairies are dominated by few species of perennial grasses with a large numbers of satellite species filling the remaining space (Glenn 1990).

Short grass prairies, such as those found in Pennsylvania, are found in xeric soil environments with hot summers and cold winters (Lawless, et al 2006). These grasses are more common in the central region of the United States and in higher elevations as compared with the tall grass prairies. The grasses can reach heights of approximately three to five feet (Glenn 1990). This type of prairie has the distinct characteristic soil called Mollisol, which has rich organic soil with good aeration and drainage (Beniston 2009).

At the Pennsylvania State University Arboretum, located in State College, PA, a prairie restoration project was started in 2001 as part of a graduate thesis project by Daniel Laughlin. Originally, the site selected for restoration was a mixture of both exotic and native herbaceous plants. Specific exotic plant species were not recorded in original studies in the Prairie Grass Restoration Area completed by Laughlin because the focus of the study was to recreate the original prairie habitats of central Pennsylvania (Laughlin 2002). However, Laughlin stated that the most common exotics that pose a threat to the prairies in the northeast United States are *Centaurea maculata*, *Eleagnus umbellate*, and pasture grasses such as *Festuca elatior* and *Dactylis glomerata*.

The treatment area in which the original restoration efforts took place had the necessary characteristics the original grasslands found in Pennsylvania had such as soil type and a high density of native plant species. The soil was characterized as a xeric limestone soil with rocky outcroppings (Laughlin 2002). This site was characterized by a mix of short-grasses and was 0.08 hectares in size. In Laughlin's studies, there were many native prairie plant species that were found in the study area including, but not limited to, *Bouteloua curtipendula*, *Lithospermum canascens*, *Solidago rigida*, *Bromus kalmii*, *Panicum oligosanthes*, and *Silphium trifoliatum* (Laughlin 2002). Laughlin determined that Centre County had the highest density of rare plants found in limestone prairies in Pennsylvania.

Laughlin developed a restoration plan that included the reestablishment of common native grassland species. Native seed was collected from over 20 native prairie plants at local prairie remnants and germinated in the Forest Resource Laboratory greenhouse on the Penn State campus. These seedlings were planted in the first week of June 2001. Species that have become established on site and persist today include sideoats grama (*Bouteloua curtipendula*), prairie brome (*Bromus kalmii*), long-headed anemone (*Anemone cylindrica*), rigid goldenrod (*Solidago rigida*), whorled rosinweed (*Silphium trifoliatum*), wild bergamot (*Monarda fistulosa*), and butterflyweed (*Asclepias tuberosa*). Many of these species, specifically sideoats grama, are rare and endangered species within Pennsylvania.

Since the original restoration efforts by Laughlin, the site has been left unattended with minimal mechanical removal of invasive plant species. During this time, several invasive species have returned to the site causing the treatment site to be a mix of prairie grasses and unwanted invasive species. Dr. Kim Steiner and other researchers at the Pennsylvania State University have decided to rekindle this project on in hopes of returning and maintaining it as prairie grassland.

Historically these grasslands provided a unique habitat for animal communities found within Pennsylvania. Small mammals (<5 kg) thrive throughout these grassland environments, using the habitat for protection and a food source (Thompson and Gese 2013). While it is currently unknown what species persist in the treatment site, it could provide habitat for species that have a preference for grasslands (Table 1). Furthermore, it can be expected that communities of small mammals will respond to the restoration given that many of these species are specialists to grassland habitats (Thompson and Gese 2013).

This restoration will be affecting small mammal populations by first altering the current vegetative community and then reestablishing a rare endangered ecosystem. My goal was to understand how these restoration treatments would affect small mammal communities. More specifically, I wanted to 1) establish a baseline estimate of small mammal composition and species diversity; 2) evaluate how the first stages of a prairie grass restoration affects small mammal species composition and diversity; 3) determine if the treatment site where ongoing restoration plans has higher small mammal relative abundance compared with the area that represents how the treatment area originally looked prior to 2001; and 4) determine the relative population density in each study area.

I had several hypotheses that correlated with my objectives to study this treatment area and compare it with a control area in which the invasive plant community was not removed. I hypothesized that 1) small mammal species in the treatment site would include the deer mouse, white-footed mouse, southern red backed vole, meadow vole, and meadow jumping mouse, some of which are habitat generalists and others that are specialists for grassland habitat. In the control area I expected to find species such as the southern bog lemming, woodland jumping mouse, deer mouse, southern red backed vole, woodland vole, and white-footed mouse since the control site has a habitat suitable species that prefer shrubby and woody habitat; 2) the treatment area would have a higher relative abundance and higher estimated population size compared with the control area because of plant species composition and the difference in amount of ground cover; 3) the treatment area will have a more diverse and even small mammal species composition; and 4) the treatment area would have a higher relative population density of small mammals compared with the control. This study will give a more rounded research perspective to the

Prairie Grass Restoration project by understanding how not only grass species are affected but also how the wildlife community is being affected.

MATERIALS AND METHODS

Study Area

This project took place in the prairie grassland treatment area in the Arboretum at the Pennsylvania State University in Centre County, Pennsylvania (Figure 1) during the summer of 2012. Currently the restoration process is still ongoing. The study area is located within the temperate deciduous forest biome with a climate consisting of warm, humid summers and cold, wet winters. Temperatures ranged from 4-28 degrees C in May and 9-36 degrees C in June through August. Rainfall ranged from 0 to 0.58 cm for most of the summer. Humidity ranged from 41% to 94% (PSC 2012). The elevation of this area was approximately 335 meters above sea level. In 2001, mechanical and chemical removal was conducted on the treatment site along with planting native grass species. These species included sideoats grama (*Bouteloua curtipendula*), prairie brome (*Bromus kalmii*), long-headed anemone (*Anemone cylindrica*), rigid goldenrod (*Solidago rigida*), whorled rosinweed (*Silphium trifoliatum*), wild bergamot (*Monarda fistulosa*), and butterflyweed (*Asclepias tuberosa*). Most of the seeded grassland species have become established in the treatment area, however, invasive species have also arisen including a variety of privet species (*Ligustrum*) and Canada thistle (*Cirsium arvense*). Currently, the restoration efforts include chemical and mechanical removal of invasive species throughout a 2.02 hectare treatment site.

In addition to the vegetative structure, soil and land composition are important in determining species that may inhabit this area. The area is characterized by well-drained, shallow limestone soil. There are rocky outcroppings throughout the treatment area. The slope of the treatment area faces a northwest direction. The study area is representative of other prairie remnants found throughout Pennsylvania such as Westfall Ridge Prairie in Juanita County, which are characterized by limestone soil and native plant species such as side oats grama and false gromwell *(Onosmodium molle)*(TNC 2013).

The Control Area represents an area that had the same original conditions in terms of vegetation community as the treatment area prior to Laughlin's studies but did not receive mechanical removal or the native planting treatment. This site was included to obtain a baseline understanding of what the treatment site looked like before any restoration efforts were put in motion. It has a slope facing in a southward direction. This area is also characterized as having well-drained, shallow limestone soils. There are a variety of species found in this area including pokeweed (*Phytolacca*), garlic mustard (*Alliaria petiolata*), purple loosestrife (*Lythrum salicaria*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), English ivy (*Hedera helix*), Japanese honeysuckle (*Lonicera japonica*), privet (*Ligustrum obtusifolium*), bush-honeysuckle (*Lonicera tatarica*), multiflora rose (*Rosa muliflora*), autumn olive (*Elaeagnus umbellate*), staghorn sumac (*Rhus typhina*), and sweet fern (*Comptonia peregrine*). There were few native prairie grass species in this area including sideoats grama and prairie brome. Due to the structure of many of these plant species, the area forms a thick ground cover, which likely affects the composition and species diversity of small mammals within the area.

<u>Field Methods</u>

Establishing Trap lines

I established four 100 meter transects: two in the treatment area and two in the control area. Each transect was separated by a minimum of 100 meters along the entire length of each. The start location was randomly chosen for each transect (Figure 1).

These transects were set up in the spring and were checked daily through the summer breeding season. Each transect consisted of 10 Sherman box traps with 10 meters spacing. This method was used to treat each study area as its own sample and each trap as a subset of that sample. In both study areas traps were set up in the grassy areas or dense foliage and near observed surface runway paths. Traps were placed within a one meter radius of the transect centerline to enable traps to be close to observed runways if present.

Setting the Traps

Small mammals were able to acclimate to the traps for the first week of the study. During this week trigger levers were set to allow small mammals to enter the traps without being captured. Once animals have become familiarized with the traps, capture efficacy is likely to increase (Gervais 2010). Traps were checked daily to add more bait and ensure animals were still entering traps. This also allowed the opportunity to monitor general activity levels surrounding the traps, such as if the bait in the trap was eaten or if the bait was left untouched. After the first week, trigger levers were re-set to spring when small mammals entered the traps. Protocol was approved through the Pennsylvania State University's Institutional Animal Care and Use Committee (#40305).

Many of the small mammals expected in the project area are mostly nocturnal or crepuscular, meaning they are active during the late evening and early morning. The presence of multiple species in the project area during these times compels animals to partition resources and limited competition between individuals (Thompson and Gese 2013). Animals are active at these times to decrease predation (Thompson and Gese 2013). I established a trapping protocol to target species active during these time periods. Traps were set during the evening at approximately 1900 hours and were checked in the morning beginning at 0730 hours. Due to the high temperatures and humidity experienced in this area during the summer months, traps were not set during the day to ensure safety of the captured mammals. In addition to maintaining animal safety, traps were baited with peanut butter each time they were set to ensure enough food was provided and each trap had a piece of cotton to assist the animals in thermoregulating their temperatures while trapped overnight (Ganey and Chambers 2011).

Animal Captures

Traps were checked in a consecutive order starting with Line 1 and ending with Line 4. When an animal was captured, it was processed and immediately released. Animals were ear tagged, sexed and identified to species level after capture. Measurements were also taken of body length. Each trap was closed after the morning survey to ensure no animals were caught during the day. Traps were reset in the evening to be checked the following morning.

<u>Data Analysis</u>

Relative Species Abundance

To determine if the treatment area had higher relative abundance of small mammals compared with the control area, I calculated the number of unique individuals per transect within the treatment and control. Relative species abundance is the mean number of unique individuals captured for each species in each study area. Standard deviations and standard error were calculated to account for variance in the samples.

Once the relative abundance values were determined a T-test was conducted to determine if there were significant differences in abundance between study sites (Kozak et al 2008).

Estimated Population Size

To establish a baseline estimate to evaluate how a prairie grass restoration affects small mammal species abundance, I calculated the estimated population size. This is the estimate of the total number of individuals for each species. Unlike the relative abundance, the estimated population size takes the mark-recaptures into account. Relative abundance only factors in the number of individuals captured throughout the study period. The population size of each species was calculated using the Lincoln-Petersen equation (Wilson et al. 1996):

$$\widehat{N} = \frac{MC}{R}$$

Where $\widehat{N}$ is the estimated population size of a given species within a given area, while M is the total number of individuals captured and marked on the first week, C is the total number of individuals captured in the second week and R is the number of individuals captured on the first week that were then recaptured on the second week. This equation was applied to all weeks of the study.

Relative Density

To determine the density of small mammals in each treatment area, I calculated relative density, which provides a unit specific measure of abundance. This was calculated by treating each transect line as a given area. Since the relative home ranges of small mammals observed in this study varied from 10 m^2 to 100 m^2, each trap was considered a subsample of the transect line in which it was assumed animal home ranges did not overlapped. Determining relative density within each study area was completed by using the equation:

$$D = \frac{N}{2Lw}$$

Where N represents the number of unique individuals captured during the study period divided by two times the length (L) times the width (w). Lengths were the distance of the transect line, 100 m. Following other research protocols, the widths were determined at 10 meters (Wilson et al. 1996). Density per m^2 was then converted to density per hectare.

Species Diversity and Species Evenness

Species diversity is an index that incorporates the number of species in an area along with the relative abundance. Species evenness determines how evenly distributed different species are in terms of abundance of each species within the sample area. These were calculated to compare the species composition of each habitat. Two formulas were used to determine both species diversity and species evenness: Shannon-Weiner Index and Simpson's Index (Magurran 2004). The Shannon-Weiner Index for diversity (H') is:

$$H' = -\Sigma(p_i \times \log(p_i))$$

Where p_i represents the proportion of individuals belonging to the *i*th species in the sample. The Shannon Index values range from 0 to 4.5. As the index approaches 4.5 it indicates both a high species diversity and equal population abundance. The evenness equation used for Shannon-Weiner (E) is:

$$E = \frac{H'}{H_{max}}$$

Where H' is the index calculated from the previous equation and H_{max} is calculated by calculating H' assuming perfect evenness. The result of this metric can be interpreted such that as the evenness value approaches one there are equal numbers of each species present.

Simpson's Index (D) is similar to the Shannon Weiner Index, however it measures the probability that two individuals randomly selected from a sample will belong to the same species (Magurran 2004). This index is heavily weighted towards the most abundant species in the sample and is less sensitive to species richness. However, it does demonstrate the variance of the species abundance within each sample. The equation is as follows (Magurran 2004):

$$D = \frac{\Sigma(n(n-1))}{N(N-1)}$$

Where n is total number of individuals of a particular species and N is the combined number of individuals across all species. Diversity is calculated by subtracting D from one. As D increases, diversity decreases meaning that with a larger D value there will be a smaller amount of diversity in the population. The measure ranges from zero to one with one representing infinite diversity and 0 representing no diversity.

To calculate evenness using Simpson's Index, this equation must be used:

$$E = \frac{1/D}{S}$$

Where D is the previously calculated number and S is the number of species in the sample. This measure also ranges from zero to one with the same interpretations as the diversity index.

Both indices were used because they allow for a more clear and thorough analysis of the community composition. As previously stated, each index focuses on different aspects of diversity and evenness. Determining diversity and evenness using the Shannon-Weiner Index and the Simpson's Index enabled me to establish a baseline study of small mammal species diversity and evaluate how a prairie grass restoration affects small mammal species diversity.

RESULTS

The study was conducted over a total of 65 nights with 40 trap lines making 2600 potential trap nights throughout the summer of 2012. There were a total of 182 sprung traps throughout the study period. These traps either did not spring when an animal entered it or it sprung by itself without an animal in it. These errors were calculated into the trap nights but still could have affected the number of animals captured or recaptured. The sprung traps were subtracted from the potential trap nights, meaning there were 2418 effective trap nights.

There were a total of 407 individuals captured in both study sites and were comprised of five different species. There were 218 captured in the Treatment area and 189 captured in the Control area. In the treatment area, I captured a total of 70 meadow voles, 58 deer mice, 80 white-footed mice, and 10 red-backed voles. In the control area, there were a total of 57 meadow voles, 68 deer mice, 42 white-footed mice, 12 red-backed voles, and 12 woodland voles. Non-target species including black rat snake (*Pantherophis alleghaniensis*), white tailed deer (*Odocoileus virginianus*) and ground hogs (*Marmota monax*) and were recorded from direct observations (Appendix 1).

Relative Abundances

The relative abundances showed little differences in species composition throughout both study sites (Figure 2). The relative abundance of meadow vole (p=0.447), deer mouse (p=0.742), and red-backed vole (p=0.795) did not differ significantly between study sites. However, white-footed mice (p=0.048) showed a significant difference between the treatment area and the control area.

Estimated Population Size

The treatment area had higher estimates for population throughout the summer in most species (Figure 3 and Figure 4). There are no specific patterns that can be seen from viewing the treatment area at a community level, but it can be seen that the white-footed mouse increased in population size when many other species decreased from weeks two to four. It can be noted that in the control during week six, there was a significant decrease in population size of all species. The species with the lowest overall estimated population size was the red-backed vole.

Relative Density

Relative density was determined by the per hectare value. In the treatment site two species, meadow voles and white-footed mice had a higher relative density as compared with the control site (Figure 5). The deer mouse and red-backed vole had higher relative densities in the control site as compared with the treatment site. The relative density of the woodland vole showed a significant difference between the two study sites since this species was only found in the control site. Overall, the treatment site and the control site had similar relative densities when comparing community levels for small mammal species.

Diversity and Evenness

Species diversity measured by the Shannon-Weiner Index was higher in the Control area (H'=1.41) as compared to the Treatment area (H'=1.23) (Table 2). Species evenness was higher in the treatment area (E=0.88) as compared with the control area (E=0.87), but these values did not differ significantly between the two study sites. The Simpson's Index supported the Shannon-Weiner Index with similar results on diversity and evenness.

DISCUSSION

Relevancy to Prairie Grass Restoration

This research demonstrated that the current restoration efforts have had little effect on small mammal populations thus far. One major component that must be taken into account of this research is that this is the first year that the restoration efforts are being conducted since the original efforts in 2001. Also this restoration is predicted be an eleven year process, meaning that the "first year" will not have a significant change in habitat quality. The relative abundance, estimated population size, relative density, and diversity and evenness indices support this claim by showing that while there were minor significant differences within species, overall, there is currently no change in small mammal populations. This is to be expected since the main sources of invasive plant removal were mainly from chemical removal and minimal mechanical removal. However, it can be seen from the one species captured that the two sites are slowly beginning to show some differences in habitat types specifically with plant composition that will soon affect the connection with the food chain of these small mammal species.

Small Mammal Ecology

Many of the species expected in the treatment site were present except for the meadow jumping mouse. The control site had many of the same species as the treatment except the woodland vole, demonstrating that the habitat type in this area was different enough for this species to recognize. However, other species that were expected and not present in the control site included the southern bog lemming and the woodland jumping mouse. Since these two species usually prefer habitats with more of a forested environment with deciduous trees (Shenko et al. 2012), and the current control area has minimal tree growth, it is likely that these species are not present because of the habitat conditions.

Relative abundance and relative density were similar for each species in the study sites. This may be due to the fact that the prominent species captured were generalist species and would likely be able to thrive in both study sites (Merritt 1987). Also, the relative density coincided with the relative abundance values and demonstrated that each species had similar densities within the ranges reported by Merritt (1987) (Table 1).

Estimated population sizes also support the claim that the restoration efforts have had little impact on these species. Throughout the time period of the study, there was chemical and mechanical removal of invasive species. Specifically, between Week 5 and Week 6 a chemical spray was distributed over the treatment site for invasive species control. This chemical spray is a one possible action that may have aided in the decline of species within the treatment area. Most species in this area were already declining and only the white-footed mouse received a significant impact. Besides this drop in the estimated population size, there are no other significant patterns in this data. This possibly suggests that individuals were not being affected by other restoration efforts such as mechanical removal. The control site is similar to the treatment site in that three species significantly declined between Week 5 and Week 6 and that there are no other patterns in the data. At this time it is unknown exactly why this happened, but some possibilities include increased predation or even the possibility that that some of the chemical spray was distributed to the control site from wind.

All but one species, the white footed mouse, demonstrated similar patterns of abundance in both study sites. However in the measurements of estimated population size the white-footed mouse values are similar. This may be due to the fact of the amount of recaptures with this species was larger compared to other species in both study sites. The relative density for this species was correlated with relative abundance and may have been smaller in the control because other generalist species, such as the deer mouse and meadow vole, and specialist species, such as the woodland vole, were competing for the same area. While these species, except for the woodland vole, would also compete in the treatment site as well, it is possible that the treatment site had better food sources in terms of seeds and grains as compared with the control and this caused more individuals per area in the treatment site. However, it is also possible that this data is biased since it was such a small sample size.

The woodland vole is also a distinctive species that was only observed in the control area. As previously stated, this is a good indicator that the control site has a different in plant composition as compared with the treatment site. The transect line that most of the woodland voles were captured in was near dense stands of woody shrubs, which is perfect habitat for this species (Merritt 1987). This would also explain why they had such a small relative density as compared with other species observed since their preferred habitat was rare across both sites.

Overall the species diversity and evenness confirms what all other measures demonstrate. The species diversity and evenness values were similar between the two study sites. The similarities in measurements between study sites may be due to the fact that while the treatment site has many prairie grass species, it still has several invasive species that are competing with these grasses, which can be affecting the habitat conditions for these small mammal species. Ground cover might be one key aspect of these conditions that is still developing in the treatment area. While many prairie grasses allow for high coverage and loose covering that is close to the ground for small mammal runways, many invasive species create thick underbrush and the inhibit the ability for small mammals to make these runways to travel to different areas within their home range (Thompson and Gese 2013). Another key condition is food sources. Prairie grasses give small mammals a good source of seeds, buds and stems (Thompson and Gese 2013). This habitat also provides them with insects that feed on these plants. However, the invasive species may also be inhibiting the production of food for these animals in the treatment area (Bateman and Ostoja 2012).

Sampling scheme

While conducting this project, there were several errors that could have affected the data. There were some problems with the protocol throughout this study time period. There were a few animals that escaped when they were being processed. Some either escaped before they were ear tagged or before all measurements were able to be taken. These individuals were not included in the results. Another problem was that I was unable to trap consecutively throughout out the summer due to temperatures above safe trapping environments and when the Arboretum employees were spraying the treatment site with pesticides. This may have affected the values and calculations, especially for the estimated population size. The final error that was observed was the possibility of misidentifying individual animals at the beginning of the study. Specifically, deer mice and white-footed mice were originally difficult to differentiate when being processed, especially when these two species have been known to hybridize (Thompson and Gese 2013).

Future Implications

This research will be continued on for the next several years to coincide with restoration efforts to determine how small mammals will be affected with more invasive mechanical removal including controlled burning, labor removal and the planting of native prairie grass species. With the changing habitat in the future, it can be expected that new species or more individuals will be moving into the treatment area. It would be interesting to observe how other wildlife species such as herpetofauna, insects, and avian populations are being affected by these changes. It will also be interesting to observe how these wildlife species affect the growth of new plant communities whether they inhibit growth or encourage growth.

Table 1. Potential species that will be trapped in both the Prairie Grass Restoration (treatment) site and the control site from June-August of 2012. These data, including expected density, are based on the range and habitat of each individual species (Merritt 1987, Ganey 2011).

Species	Behavior	Habitat	Diet	Density (per hectare)	Expected location	Actually Found
Deer Mouse (*Peromyscus maniculatus)*	Nocturnal; forages for seeds	Every terrestrial habitat (fields to woodlands)	Variety of seeds, nuts, berries and insects	8-90	Treatment and Control	Treatment and Control
White-footed Mouse (*Peromyscus leucopus*)	Nocturnal; nests in groups; forages on nuts, seeds and insects	Broad spectrum of habitats	In summer grass seeds and fruits; insects	6-38	Treatment and Control	Treatment and Control
Southern Bog Lemming (*Synaptomys cooperi*)	Active day and night Uses surface runways made from dead grass coverage	In old fields interspersed with wood vegetation	Succulent stems, leaves and seeds of grasses and sedges	4-12	Control	Not Found
Southern Red Backed Vole (*Myodes gapperi*)	Mostly nocturnal; locomotion is hopping or running; prolific breeder	Rocky-outcroppings with stumps, roots, and rocks exposed; common in mixed forests	Opportun istic feeder; seeds, nuts, berries, arthropod s, lichens	2-38	Treatment and Control	Treatment and Control
Meadow Vole (*Microtus pennsylvanic us*)	Active day and night; creates surface runways	Unpastured meadows and fields with grasses	Herbivor ous, grasses, sedges, grass seeds, tubers and roots	5-665	Treatment	Treatment and Control
Woodland Vole (*Microtus*	Active day and night; has	Primarily in thickets or open land	Roots, stems, leaves,	2-124	Control	Control

pinetorum)	elaborate burrowing system	and edges of agricultural land	seeds and fruits; nuts and insects			
Meadow Jumping Mice (*Zapus hudsonius*)	Nocturnal; maneuvers through foliage and hops	Abandoned grassy fields, thickets and edges of woodlands	Seeds of grasses and herbs; berries, roots and insects	4-45	Treatment	Not Found
Woodland Jumping Mice (*Napaeozapus insignis*)	Nocturnal; slow gate in underbrush and can jump long distances	Woody areas and thickets but rarely in open fields.	Grassy seeds, insects	1-59	Control	Not Found

Table 2. Shannon-Wiener and Simpson diversity and evenness indices for small mammals observed in the treatment area and the control area of the Prairie Grass Restoration in the Penn State Arboretum. These data were collected from June-August of 2012.

	Shannon Index		Simpson Index	
Area	Diversity	Evenness	Diversity	Evenness
Treatment	1.23	0.88	3.25	0.81
Control	1.41	0.87	3.71	0.74

Figure 1. Map of Penn State Arboretum demonstrating locations of 100 meter transect lines. Lines 1 and 2 in the treatment area; lines 3 and 4 in the control area.

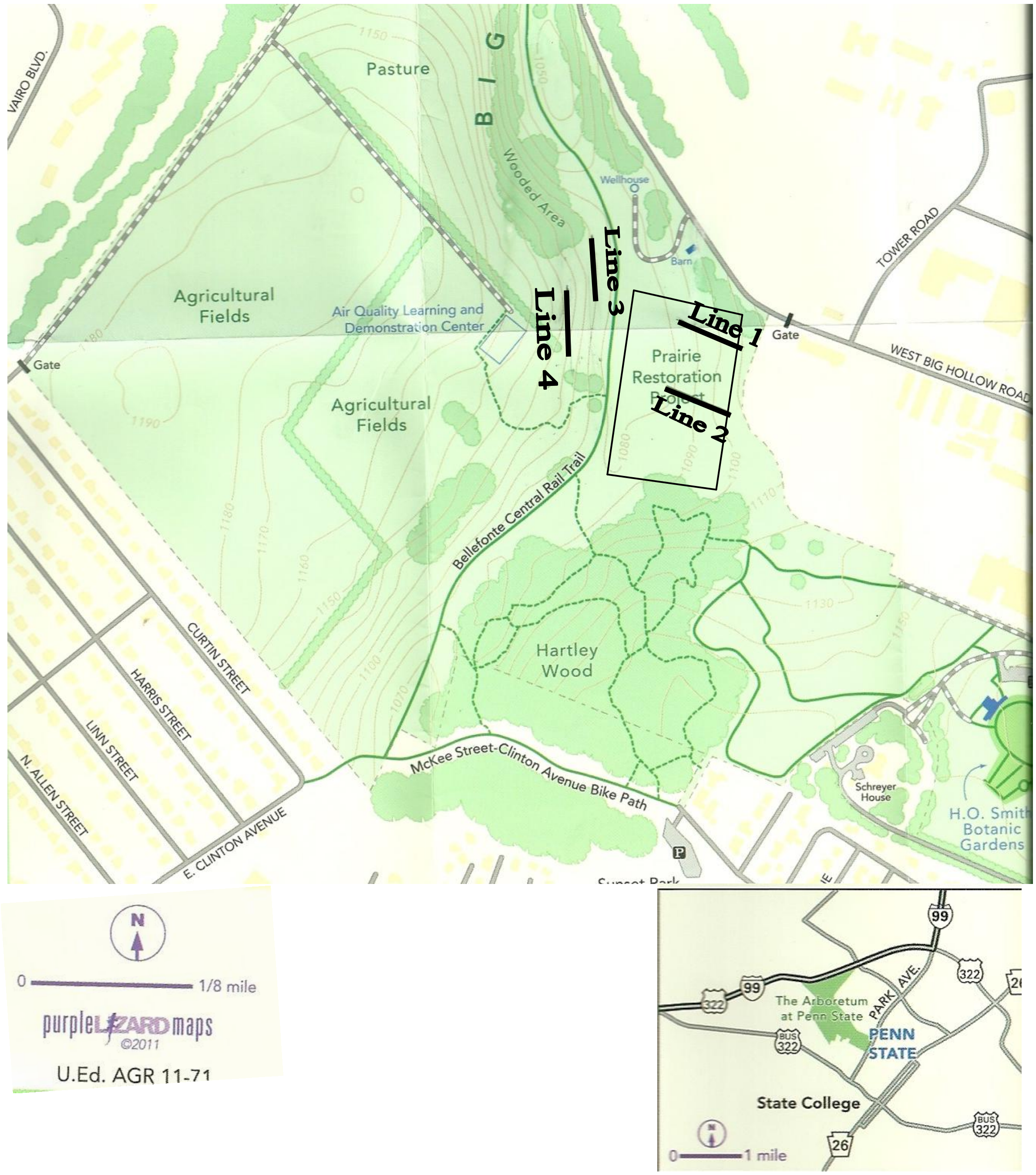


Figure 2. A comparison of the mean relative abundance of each species observed in the Prairie Grass Restoration (treatment) site and the control site in the Penn State Arboretum. The data was collected from June to August of 2012.

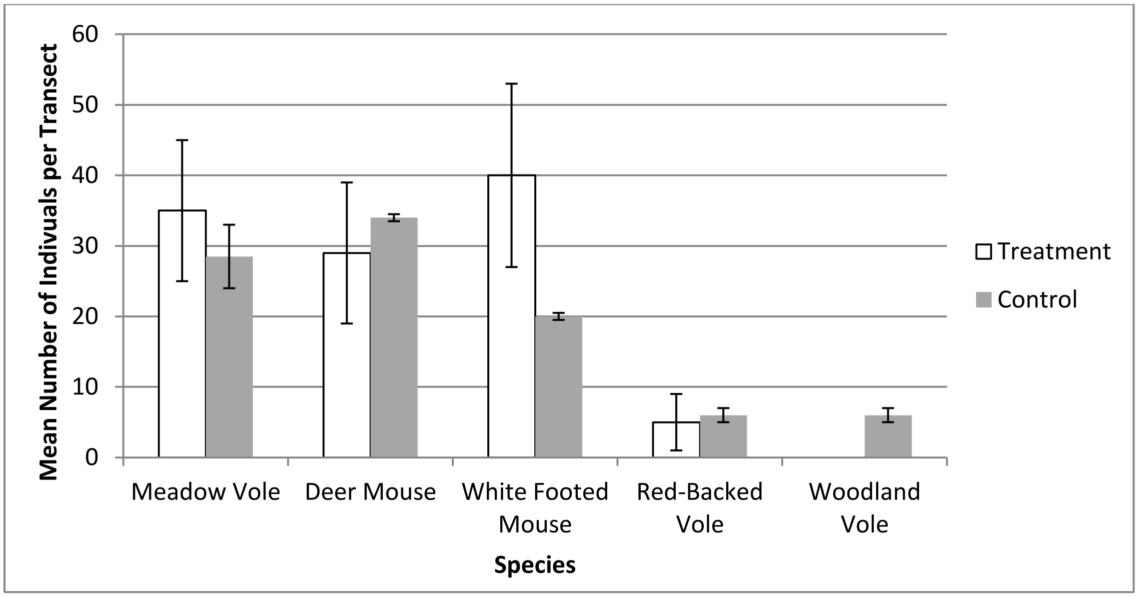
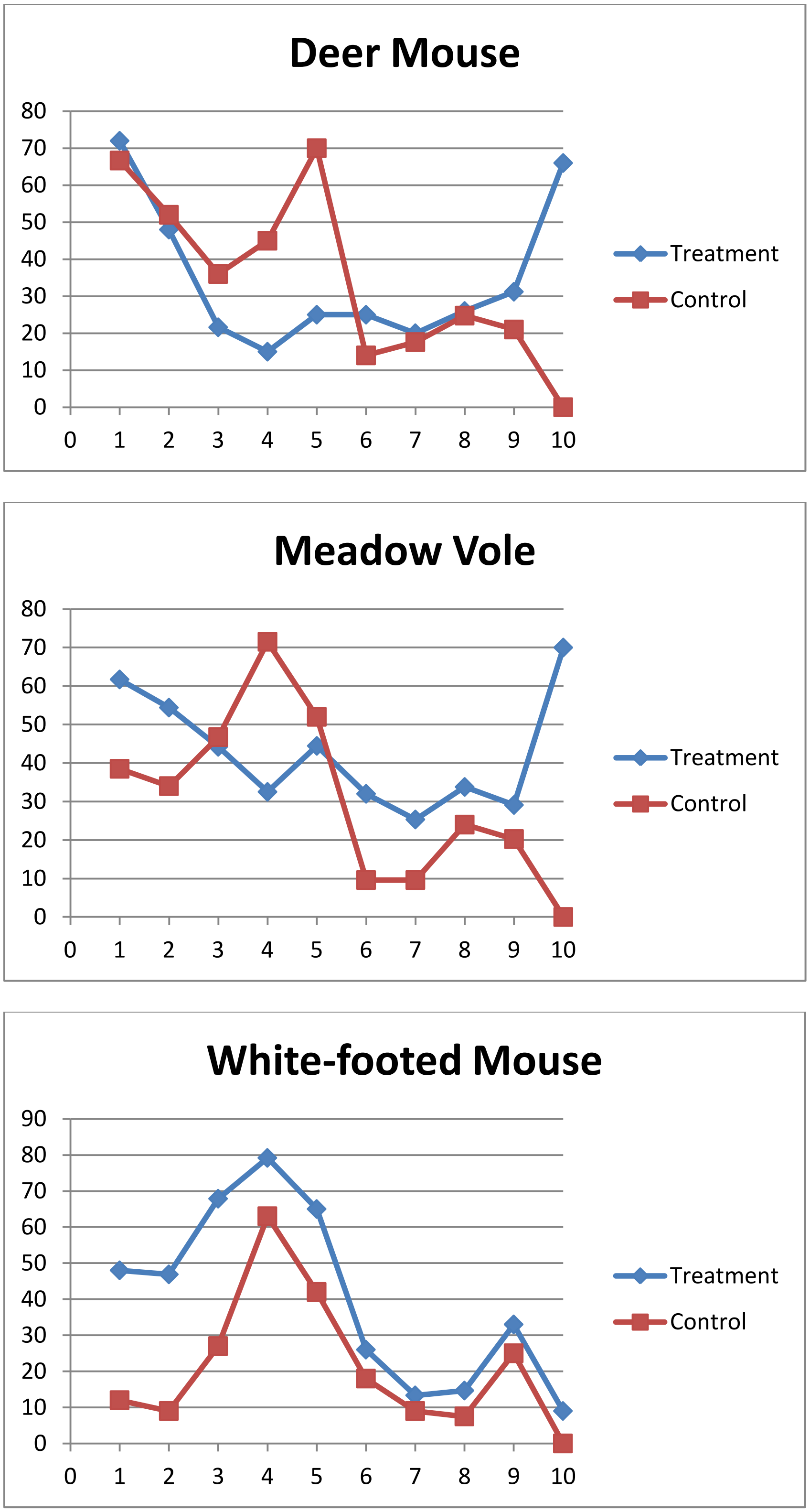
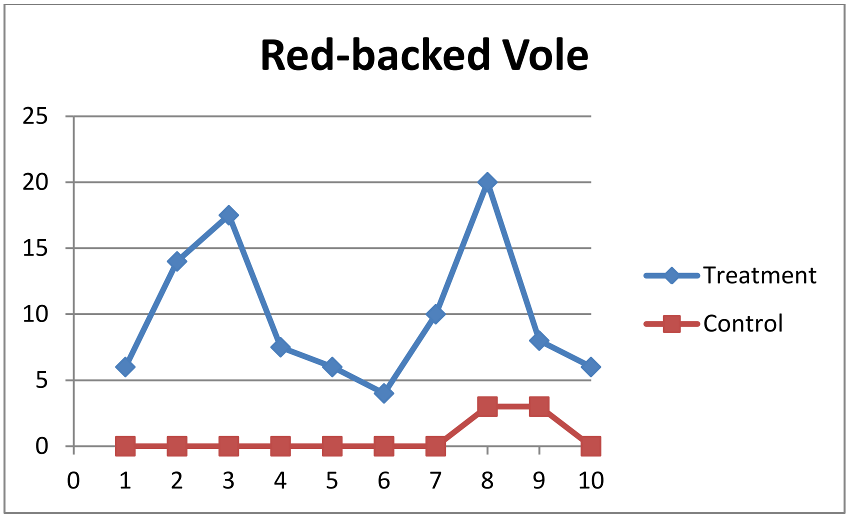


Figure 3. A comparison of the estimated population size of each small mammal species observed in the treatment and contro site for the Prairie Grass Restoration project in the Penn State Arboretum from June to August of 2012.




Red-backed Vole
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Treatment
Control

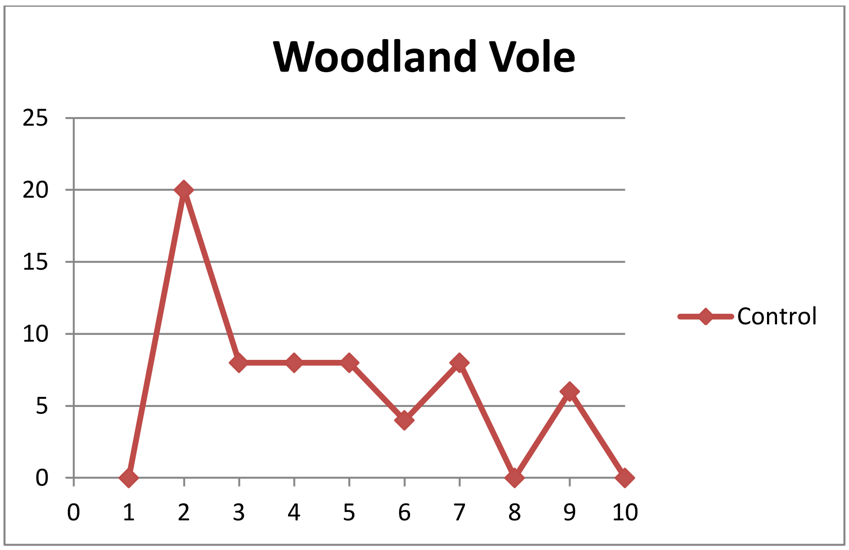
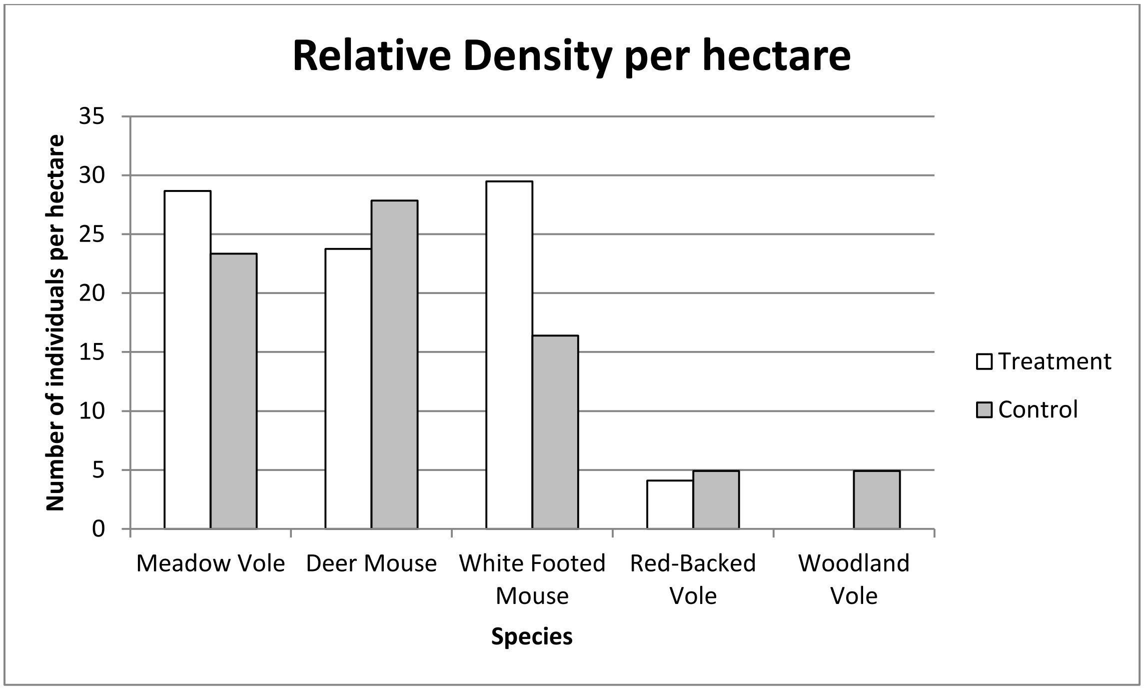

Woodland Vole
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Control

Figure 5. A comparison of the calculated relative density for each small mammal species observed in the treatment area versus the control area in the Prairie Grass Restoration project in the Penn State Arboretum. Data was collected from June to August 2012.



Appendix 1: List of incidental mammalian and herpetofuana species observations found in both the treatment and control sites of the Prairie Grass Restoration project in the Penn State Arboretum from June to August 2012.

Species	Behavior	Habitat	Found in
Black Rat Snake (*Pantherophis alleghaniensis*)	Diurnal; powerful constrictors; feed mice, rats, shrews, voles,	Variety of habitats from woodlands to grassy open fields	Treatment
White Tailed Deer (*Odocoileus virginianus*)	Mostly nocturnal and browsers	Variety of habitats, mostly wooded areas	Treatment and Control
Groundhog (*Marmota monax*)	Diurnal; foraging in pastures and fields	Open fields or forest edges supporting brushy cover	Treatment and Control

Appendix 2. Data collected on small mammal species for the number of unique individuals observed and the total number of trapped animals in both the treatment and control area for the Prairie Grass Restoration Project in the Penn State Arboretum from June to August 2012.

Study Sites	**Species**	**Transect**	**# Unique Individuals**	**Total # Trapped**
Treatment	Meadow Vole	1	25	78
Treatment	Deer Mouse	1	19	26
Treatment	White Footed Mouse	1	31	58
Treatment	Red-Backed Vole	1	9	41
Treatment	Meadow Vole	2	45	103
Treatment	Deer Mouse	2	39	101
Treatment	White Footed Mouse	2	49	89
Treatment	Red-Backed Vole	2	1	1
Control	Meadow Vole	3	24	45
Control	Deer Mouse	3	34	49
Control	Woodland Vole	3	5	5
Control	White Footed Mouse	3	20	20
Control	Red-Backed Vole	3	7	7
Control	Meadow Vole	4	33	65
Control	Deer Mouse	4	34	65
Control	Woodland Vole	4	7	26
Control	White Footed Mouse	4	22	30
Control	Red-Backed Vole	4	5	5

Appendix 3: Values for estimated population size in both the treatment and control area for the Prairie Grass Restoration Project in the Penn State Arboretum from June to August 2012.

Treatment

Species	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Deer Mouse	72	48	21.6	15	25	25	20	26	31.2	66
Meadow Vole	61.71	54.4	44.2	32.5	44.44	32	25.33	33.78	29.09	70
Red-backed Vole	6	14	17.5	7.5	6	4	10	20	8	6
White-footed Mouse	48	46.88	67.857143	79.17	65	26	13.33	14.67	33	9

Control

Species	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Deer Mouse	66.67	52	36	45	70	14	17.6	24.75	21	0
Meadow Vole	38.5	34	46.75	71.5	52	9.6	9.6	24	20.25	0
Red-backed Vole	0	0	0	0	0	0	0	3	3	0
White-footed Mouse	12	9	27	63	42	18	9	7.5	25	0
Woodland vole	0	20	8	8	8	4	8	0	6	0

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ACADEMIC VITA

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Education:

B.S. Wildlife and Fishery Sciences Minor in Forest Science, Expected: May 2014
The Pennsylvania State University, University Park, PA

Courses of Interest:

- Wildlife and Fisheries Measurements
- Wildlife Conservation
- Dendrology
- Geography (GIS/GPS)
- Plant Physiology
- Forest Resource Measurements
- Ecology
- Mammology
- Soil Sciences
- Animal Genetics

Work Experience:

Intern, Penn State Wildlife Department, State College, PA *(5/2012-8-2012)*

- Completed a research project determining how small mammals are affected by Prairie Grass Restoration-Thesis manuscript in progress
    - Identify plant communities and species within each study area
    - Research and analyze soil content
    - Constructed multiple 50 meter drift fence and pitfall traps
    - Set up 100 meter transects of Sherman Box Traps
    - Processed small mammals by ear tagging and measuring
    - Collect and analyze data
- Assisted with genetically analyzing bobcat feces from Cumberland Island
- Identified and organized mammal specimens in the Penn State Collection Database

Field Technician for Deer Survey Project, State College, PA *(8/2012-9/2012)*

- Set camera traps to determine deer densities and buck ratios in Stone Valley, PA
- Monitor cameras and reset twice a week
- Analyze pictures and complete population counts
- Identify specific vegetative habitats in each study plot

Secretary, Penn State Student Chapter of The Wildlife Society, State College, PA *(8/2011- Present)*

- ❖ Represent the organization at campus-wide meetings and functions
- ❖ Develop and present wildlife educational programs for youth and adults
    - Youth Field Day
    - Game Dinner
    - Ag Day
- ❖ Organize meetings, arrange for speakers and coordinate agendas
- ❖ Disseminate project details to membership

Awards:

Congressional Award, Gold Medal *(1/2006-4/2012)*

- ❖ Requirements include the completion of over 400 hours for each category of volunteerism and personal development, 200 hours of physical fitness, and lead a week-long expedition which my project took place hiking the trails in Sedona, Arizona

Honors Student, Schreyer Honors College
(8/2010-Present)

- ❖ The goals include dedication to academic excellence, building a global perspective while engaging in leadership and civic opportunities
- ❖ Requirements include maintaining a 3.4 GPA and completion of an honors research thesis