

THE EFFECTS OF HIGH DENSITIES OF WHITE-TAILED DEER
ON
VEGETATION IN MARYLAND



By:

Cody Adkins
Charlotte Anderson
Michelle Barillas
Holly Harlin
Annetta Hartman
Tammy Johns

Raquel Martinez
Raid Salgado
Lucas Shafer
Bailey Springirith
Kaylyn Walls
Chance Ward

July 28, 2010

Science Teacher: Kelley Flaherty
Writing Teacher: Megan Kuhns

TCs:

Julian Cook
Damani Davis

Jasmine Vaughn
Olivia Williams

ABSTRACT

White-tailed deer (*Odocoileus virginianus*) are herbivores that feed on woody and herbaceous vegetation. High densities of deer have been known to reduce the abundance of palatable plant species and cover in forests, leaving a poor habitat for other animals. We investigated whether densities of white-tailed deer affects vegetation at Catoctin Mountain Park (CMP) and Frederick Municipal Forest (FMF). Our null hypotheses were that there will be no differences between our testing sites in the mean number of stems (abundance) in the groundcover and understory levels, mean number of preferred stems in the groundcover and understory levels, mean vertical cover density, and mean Shannon-Weiner Diversity Index in the groundcover and understory levels between CMP and FMF. We used two random transects at each study site with five plots 60m apart. We used 1mx1m quadrats for groundcover and 2mx2m quadrats for understory at each plot. Vertical cover density was measured using a Robel pole. We rejected the null hypotheses that there was no difference in mean preferred stem abundance in the groundcover and understory levels, mean vertical cover density, and mean Shannon-Weiner Diversity Index in the understory level. We discovered that if high white-tailed deer densities do not decline, then there will be an effect on the future forests of CMP.

INTRODUCTION

Population ecology is the study involving the structure and dynamics of a population as they relate to the environment. A population is a group of organisms belonging to the same species in the same geographical area. Population growth depends on four main factors: immigration, emigration, mortality, and natality. The process of organisms entering a population is immigration, and the process of organisms leaving a population is emigration. Natality defines

the number of organisms entering the population by birth, and mortality is the number of organisms leaving the population by death (Enger, Ross & Bailey, 2007).

A population growth curve can be broken up into three different phases (Fig. 1). The first phase, known as lag phase, is the period of time when a population grows slowly because natality is slightly greater than mortality. The next phase is the exponential growth phase, when the natality rate is much greater than the mortality rate, and the population size grows at a continually faster rate. Stable equilibrium is the final phase when natality and mortality equal each other because of the limited resources available. Natality and mortality affect the amount of time it takes for a population to reach the carrying capacity of an environment. Carrying capacity is the maximum number per species an environment can hold because there is a limited amount of resources available (Enger, Ross & Bailey, 2007).

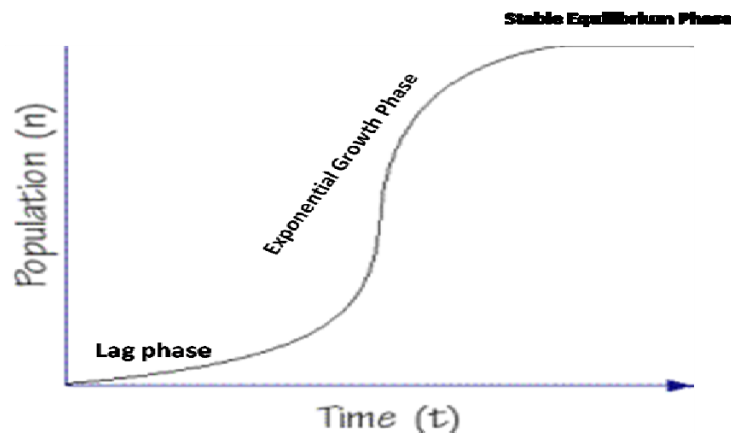


Fig. 1.- A typical population growth curve.

Population mortality and natality rates are affected by limiting factors. There are two types of limiting factors, density-dependent and density-independent factors. Density-independent factors are factors caused by outside sources like weather and natural disasters that impacts the population regardless of its size. Density-dependent factors are limiting factors that rely on the density of the deer population and include predation, disease epidemics, and

competition for resources (Enger, Ross & Bailey, 2007). Predators increase as the prey population increases because there is more food available for them. Diseases are more common in larger populations because they can transfer faster. Competition for resources such as food, water, and shelter increases if a population increases because there are more organisms fighting for survival (Enger, Ross & Bailey, 2007).

White-tailed deer (*Odocoileus virginianus*) are herbivores found all over North and Central America (Fergus and Shope, 2007). They are part of the Cervidae family because they have split hooves, and are considered ruminants because they have a four-chambered stomach allowing the herbaceous and woody species they eat to be digested easily (Fergus and Shope, 2007). White-tailed deer can weigh from 32-114kg depending on their habitat. They have a reddish-brown and white coat during the summer and a grayish-brown and white coat during the winter.

White-tailed deer prefer early successional habitats that provide enough cover, and herbaceous and woody species for food (Fergus and Shope, 2007). Does, female deer, breed between late-October to mid-January; healthy does can give birth to one or two fawns in mid-to late-spring. Does and fawns will then live in small groups for protection from predators, but bucks, male deer, usually only interact with other bucks outside of mating season. Natural predators of deer include: wolves (*Canis lupus*) and cougars (*Puma Concolor*); while bobcats (*Lynx rufus*), black bear (*Ursus americanus*), coyotes (*Canis latarans*), and foxes (*Vulpes spp.*) prey on young fawns, who are still too young to run fast enough to escape.

White-tailed deer eat two to four percent of their body weight a day (Fergus and Shope, 2007). The majority of their diet consists of herbaceous and woody plants. An herbaceous plant is a plant that has leaves and stems that die down at the end of the growing season to the soil

level. They have no permanent woody stem above the ground which makes it easier for the deer to eat and digest. Deer eat palatable plants, the distinction between food choices based on taste, that provide nutrition (Liscinsky, Cushwa, Puglisi & Ondik, 1984). Protein is a nutrient essential for proper growth, weight gain, and milk secretions. Without proper protein intake, does run the risk of giving birth to an unhealthy fawn being unable to support the fawn or failing to conceive. This decreases natality and increases mortality. Deer need high energy foods during the breeding season and in cold weather. Many deer, especially fawns, die as a result of energy deficiencies, increasing mortality (Halls, 1984).

In the 1400s, when the Europeans first immigrated to North America, the white-tailed deer density was 3-6 deer/km² (Rooney, 2001). In the 1700s, the deer population started to decline because the colonists were over hunting the deer for food, clothing, and other personal uses. The forests were cut down for agriculture, building materials, and fuel. This destroyed the habitat of the deer. In 1730, Maryland prohibited the hunting of deer between January 15 and July 31; however, by the 1900s, the white-tailed deer were extirpated from regions of North America and only an estimated 500,000 remained in the United States (Sandt, 1997). In 1902, deer hunting was abolished in Maryland in an attempt to increase the deer population.

White-tailed deer populations started to rebound in North America in the mid-1900s. During the 1920s, many states prohibited deer hunting. Forests began to grow back, and deer predators were extirpated due to hunting. Deer were restocked into areas that had low or no deer populations (Sandt, 1997). Biologists from Maryland relocated deer from parts of Pennsylvania and other eastern shore states and relocated to Maryland. The deer population experienced an exponential growth throughout much of their range, and laws prohibiting deer hunting were relaxed or released to control the increasing deer population (Sandt, 1997). According to

Maryland records, there are more deer in Maryland than ever before. There is now an estimated 20,000,000 deer in the U.S compared to the estimated 500,000 deer in the 1900s (Toops, 1999).

Due to increased resources and strict hunting regulations, white-tailed deer populations are larger than ever. While this may be better than having no deer at all, overabundance has its own problems. High densities of white-tailed deer cause depletion of palatable vegetation and therefore affect the diversity of ecosystems. Many forests have become dominated with plants like hay-scented fern (*Dennstaedtia punctilobula*) and black cherry trees (*Prunus serotina*), because they are among the few plants that deer do not find palatable. Hay-scented fern historically covered less than three percent of Pennsylvania's forest floors. Deer do not eat the hay-scented fern because the plant is poisonous to the deer. Now, because deer devour its plant competitors, this fern dominates more than a third of the forested area in Pennsylvania and throughout the northern United States (Carson, Banta, Royo, and Kirschbaum, 2005).

As food becomes scarce, deer compete with other animals, including humans. Populations of other herbivores and omnivores, such as rabbits (*Sylvilagus spp.*) and black bears, may decline due to a lack of resources. In an extreme example, on Anticosti Island (a small island located in Quebec, Canada) scientists have documented the disappearance of both berry-producing shrubs and the black bears that feed on them (Levy, 2006). For many animals, plants provide shelter and protection. With the loss of cover, habitat for songbirds that rely on the understory is impacted (Toops, 1999).

Large deer populations not only affect other animal species, but can also affect their own populations. When a population reaches its carrying capacity, or goes over it, density-dependent limiting factors affect the population causing the mortality rate to increase and the natality rate to

decrease. This can lead to a decline in the population caused by a lack of resources such as food and cover, increased spread of disease, or increased predator populations.

The purpose of our study is to compare the effects of high and low densities of white-tailed deer on the vegetation at Catoctin Mountain Park (CMP) and Frederick Municipal Forest (FMF). We chose these sites because of the differences in deer densities caused by hunting regulations. Catoctin Mountain Park has a deer density that is three times as high as the deer density at Frederick Municipal Forest. The sites were approximately 19.6km apart from one another (Fig. 2). We chose sites that were close to each other to ensure the environmental factors and plant species would not differ greatly.

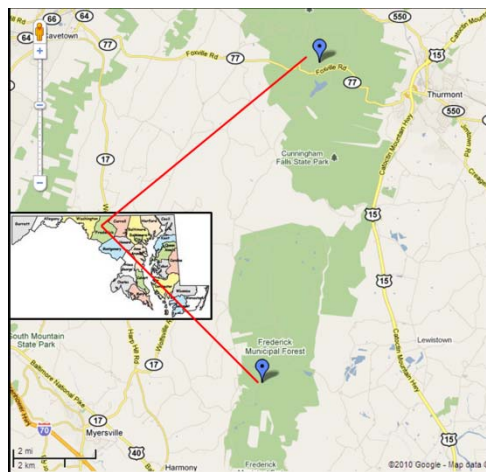


Fig. 2.- This map shows the two locations of our two study sites.

Our seven null hypotheses for our experiment are (1) there will be no difference in mean total stem abundance at groundcover, (2) there will be no difference in mean total stem abundance at understory, (3) there will be no difference in mean preferred stem abundance at groundcover, (4) there will be no difference in mean preferred stem abundance at understory, (5) there will be no difference in mean vertical cover density, (6) there will be no difference in mean

Shannon-Wiener Diversity Index at groundcover, and (7) there will be no difference in mean Shannon-Wiener Diversity Index at understory between CMP and FMF.

METHODS

We collected our data from two study sites outside of Frederick, Maryland; Catoctin Mountain Park and Frederick Municipal Forest. CMP is our experimental site because the deer densities are greater than they were at our control site, FMF. CMP is a national park. National parks have a no hunting policy that is attributed to why the deer densities are higher at CMP. The no hunting policy was put in place to try and preserve the forest's natural processes (Porter, 1999). CMP has about 48 deer/km² (National Park Service, 2010). FMF has about 16 deer/km² (Personal Communication, Brian Eiler, Maryland Department of Natural Resources). FMF is open to public hunting. This forested area was set aside for the purpose of protecting the watershed servicing the city of Frederick, Maryland. We collected our data on July 7, 2010.

We set up two random transect lines at each site. Each transect had five pairs of nested quadrats, a 1m x 1m quadrat nested in a 2m x 2m quadrat. The pairs were separated by 60m (Fig. 3). In order to measure groundcover level stems we counted and identified plants stems inside our one by one meter quadrat that were less than 30cm in height. Grass inside of our quadrats was counted in clumps. If we could not identify a plant species; we took pictures, so we could identify them later.

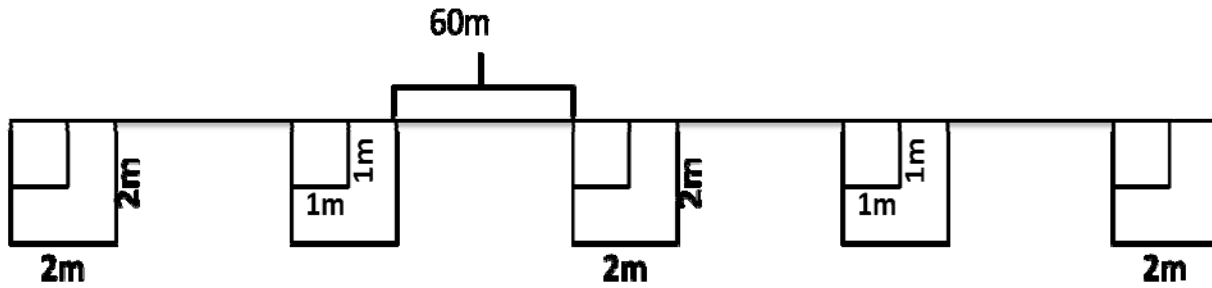


Fig. 3.- A representation of the nested plots on a transect.

When collecting understory level data we used two by two meter quadrats. In order for plants to be considered understory they had to be greater than or equal to 30cm in height, and less than or equal to 5cm in diameter at breast height(1.37m from the ground).We counted and identified all species in the understory level. When we returned to the lab, we identified plants in both groundcover and understory levels that were preferred by deer. We identified plants using information from previous studies and literature (Liscinsky, Cushwa, Puglisi & Ondik, 1984): (Miller, Miller, Bodnar, 2005).

We used the Shannon-Wiener Diversity Index to measure the diversity of the vegetation. These calculations used species counts from the groundcover and understory levels to calculate an mean diversity value for each level. This index combines species richness (number of species) and evenness (the proportional distribution of species within a community). The equation for the Shannon-Wiener Index is calculated using the following equation: $H = -\sum P_i \ln P_i$ where P_i is the proportion of each species in the sample.

We measured vertical cover using a Robel pole. We placed the Robel pole in the center of the two by two meter quadrat. A Robel pole is a 1.5 m pole with horizontal bands 10cm apart. It is used to measure the vertical cover density of vegetation. One person held the Robel pole

while another person walked 4m away, viewed the pole from a height of 1m, and documented the highest section of the pole that was obscured by vegetation. This was done from the four cardinal directions. We took the mean of the four measurements to see the mean vertical cover density in each plot.

We created bar graphs to show the means for each site and t-tests to test for significant differences between the mean total stem abundance mean preferred stem abundance, mean vertical cover density, and mean Shannon-Wiener Diversity Index (at groundcover and understory levels) at each study site. Using the t-table, we found the critical t-value of 2.10 based on a 95% confidence with a sample size of 10.

RESULTS

Catoctin Mountain Park had a total of 16 plant species, while Frederick Municipal Forest had a total of 17 plant species (Fig. 4). Five of the same plant species were found in both CMP and FMF, while 11 plant species found at CMP were not found at FMF, and 12 plant species found at FMF were not found at CMP (Fig. 4). We found several significant differences between the data collected at CMP and FMF. There were significant differences in the preferred number of stems at groundcover and understory, cover pole measurement, and Shannon-Wiener Index at the understory level.

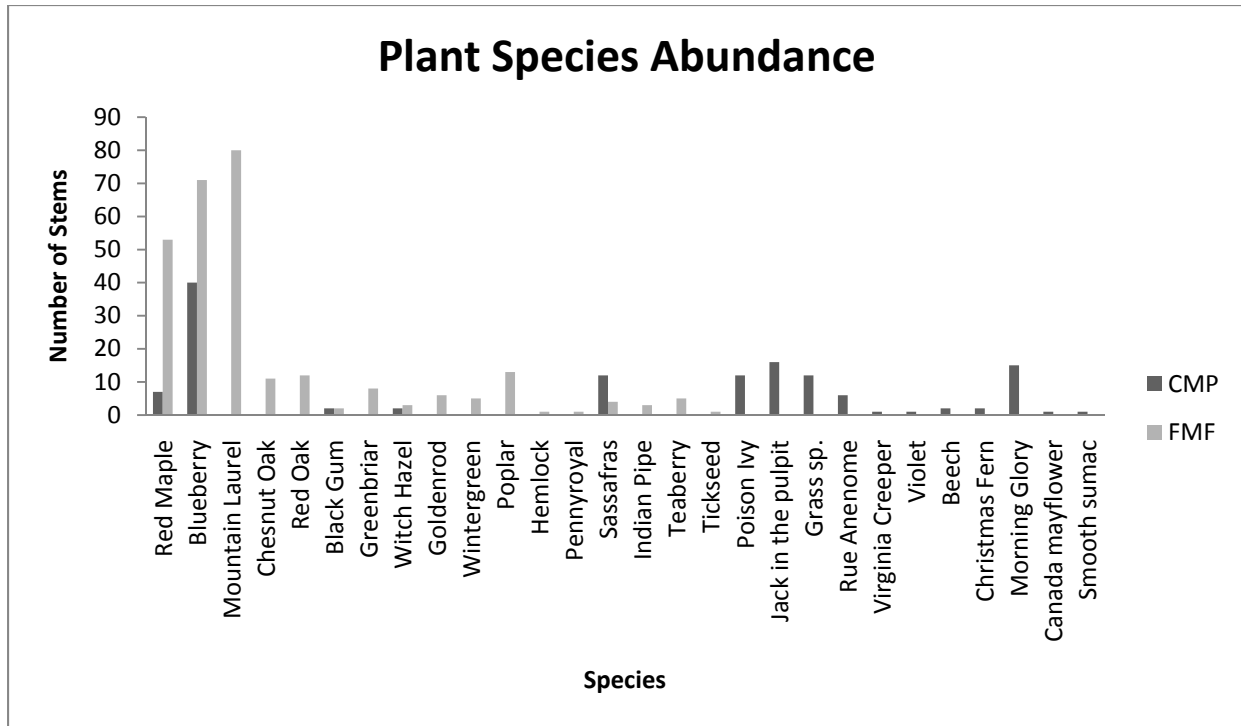


Fig. 4.- This figure displays the plant species found in groundcover and understory at CMP and FMF.

We found that the mean total stem abundance at groundcover was higher at FMF ($\bar{x}=20.5 \pm 6.1$) than it was at CMP ($\bar{x}=16.7 \pm 10.4$), but no significant difference was found ($t=0.7$, $n=10$) (Fig. 5). We determined the mean total stem abundance at the understory level was higher at FMF ($\bar{x}=8.2 \pm 4.7$) than it was at CMP ($\bar{x}=2.3 \pm 4.9$), but these results were not significantly different ($t=1.96$, $n=10$) (Fig. 6).

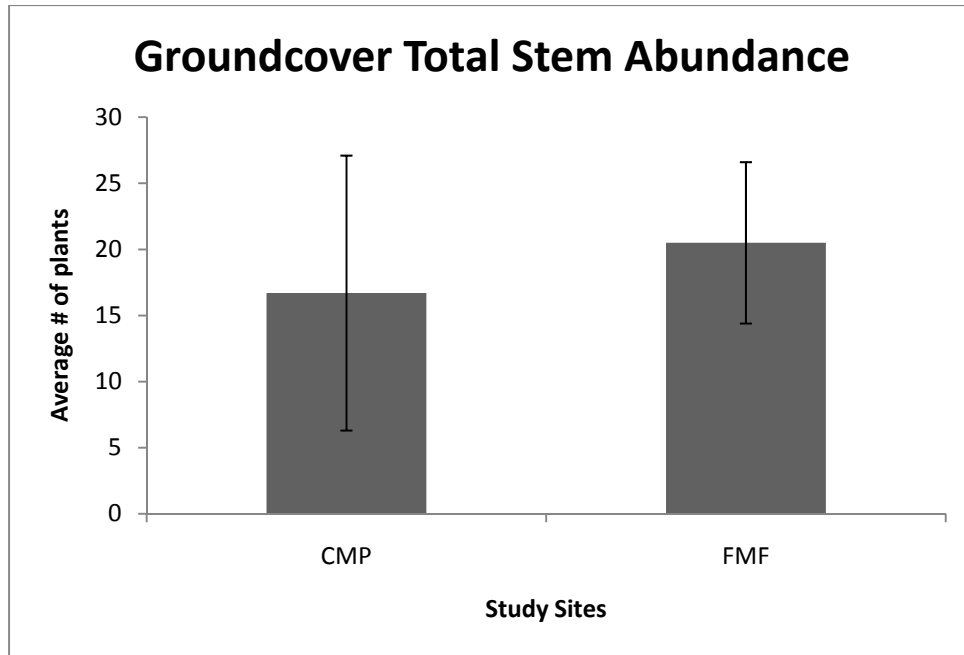


Fig.5.- This figure displays the mean of the total stem abundance at groundcover for CMP and FMF. The bars show the 95% confidence interval around the mean.

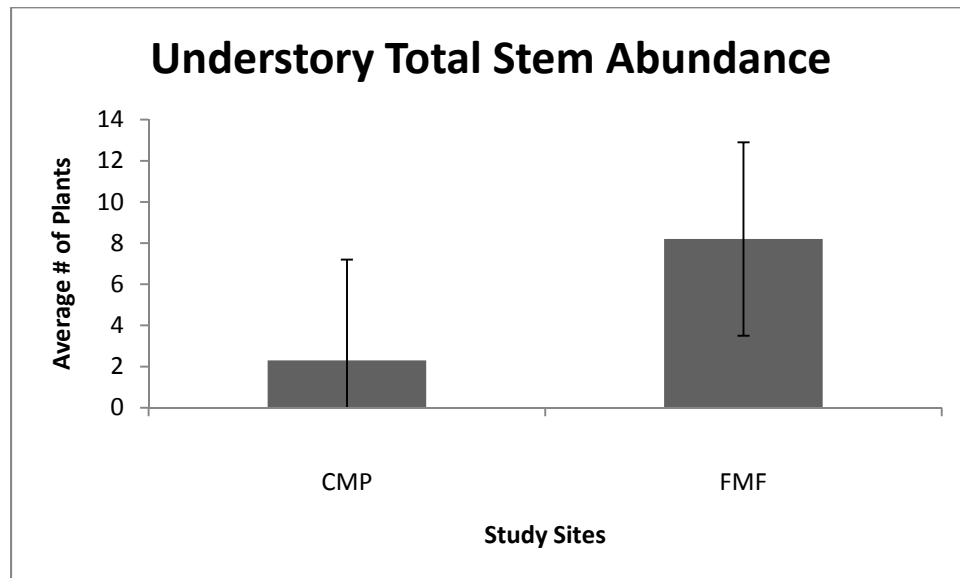


Fig. 6.- This figure displays the mean of the total stem abundance at understory for CMP and FMF. The bars show the 95% confidence interval around the mean.

We discovered that the mean preferred stem abundance at the groundcover level was higher at FMF ($\bar{x}=6.7 \pm 4.7$) than it was at CMP ($\bar{x}=1.1 \pm 0.9$), and that it was significantly different ($t=-2.7, n=10$) (Fig. 7). We found the mean preferred stem abundance at the understory

level was higher at FMF ($\bar{x}=1.9 \pm 1.6$) than it was at CMP ($\bar{x}=0.1 \pm 0.2$), and that it was significantly different as well ($t=-2.7, n=10$) (Fig. 8 and Table 1).

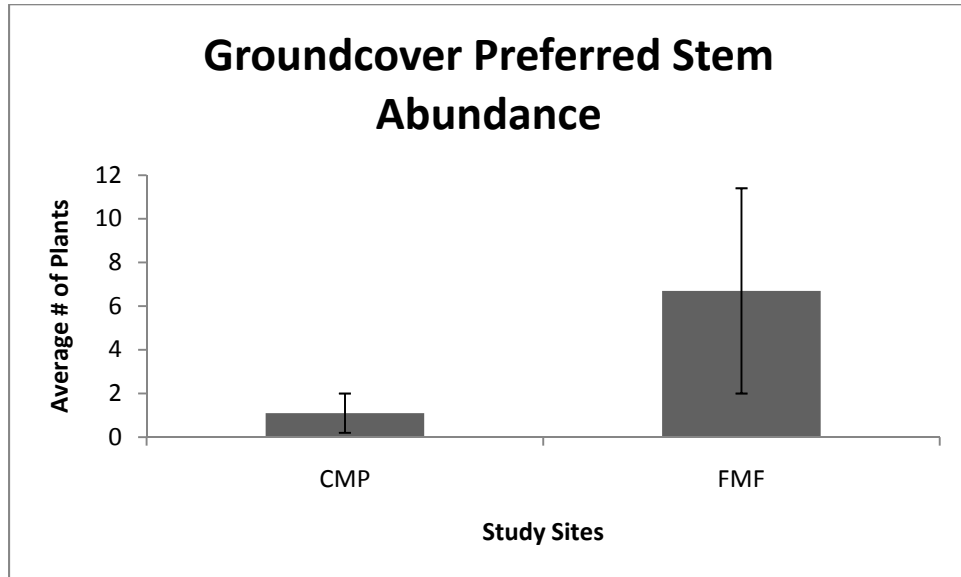


Fig. 7.- This figure displays the mean of the preferred stem abundance at groundcover for CMP and FMF. The bars show the 95% confidence interval around the mean.

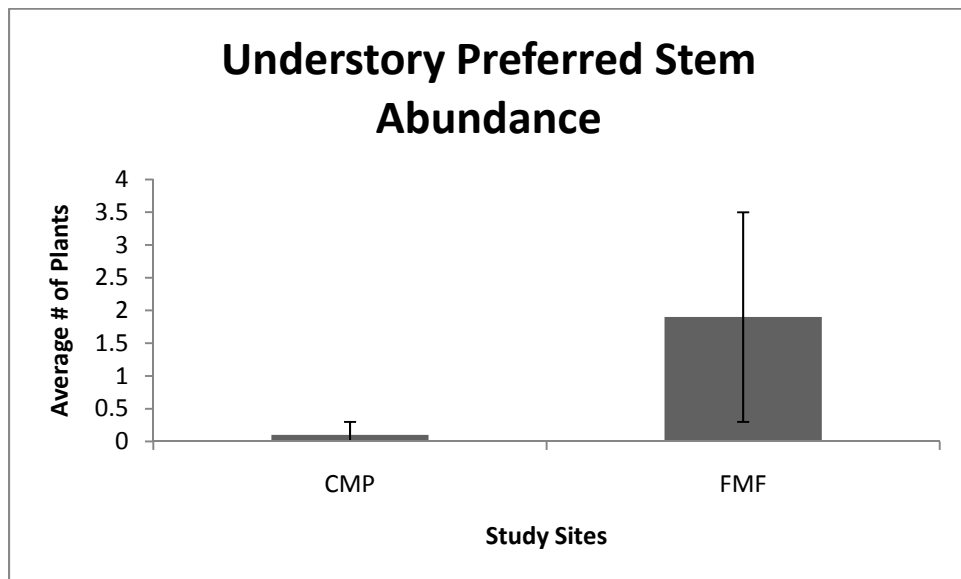


Fig. 8.- This figure displays the mean of the preferred stem abundance at understory for CMP and FMF. The bars show the 95% confidence interval around the mean.

Table 1. – Preference of observed plant species by white-tailed deer.

Species	Woody/Herbaceous	Deer Preference
Red Maple	W	High
Sassafras	W	Medium
Blueberry	W	Low
Poison Ivy	W	Low
Jack in the Pulpit	H	Low
Rue anenome	H	Low
Smooth sumac	W	Medium
Morning Glory	H	Low
Virginia Creeper	H	High
Violet	H	Low
American Beech	W	Low
Witch Hazel	W	High
Christmas fern	H	Low
Mountain Laurel	W	Low
Indian pipe	H	Low
Teaberry	H	High
Greenbriar	H	High
Red Oak	W	Medium
Spotted Wintergreen	H	Low
Tickseed	H	Low
Black Gum	W	High
Mountain Laurel	W	Low
Chesnut Oak	W	High
Tulip Poplar	H	Low
Goldenrod	H	Low
Hemlock	W	High
Canada Mayflower	H	High
Pennyroyal	H	Unknown

We determined the mean vertical cover density was higher at FMF ($\bar{x}=3.6 \pm 2.7$) than it was at CMP ($\bar{x}=0.45 \pm 1.1$), and that there was a significant difference ($t=-2.5$, $n=10$) (Fig. 9). We found that the Shannon-Wiener Diversity Index at the groundcover level was higher at FMF ($\bar{x}=1.03 \pm 0.2$) than it was at CMP ($\bar{x}=0.6 \pm 0.2$), but was not significantly different ($t=-1.95$, $n=10$) (Fig. 10). We found the Shannon-Wiener Diversity Index at the understory level was

higher at FMF ($\bar{x}=0.6 \pm 0.7$) than it was at CMP ($\bar{x}=0 \pm 0.0$), and was significantly different ($t=2.4$, $n=10$) (Fig. 11).

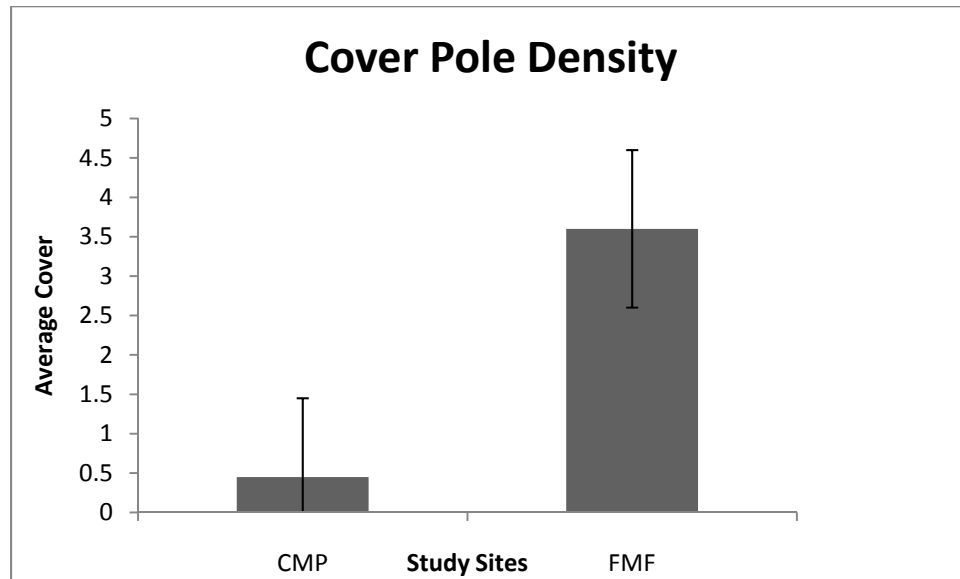


Fig. 9.- This figure displays the mean of the vertical pole density for CMP and FMF. The bars show the 95% confidence interval around the mean.

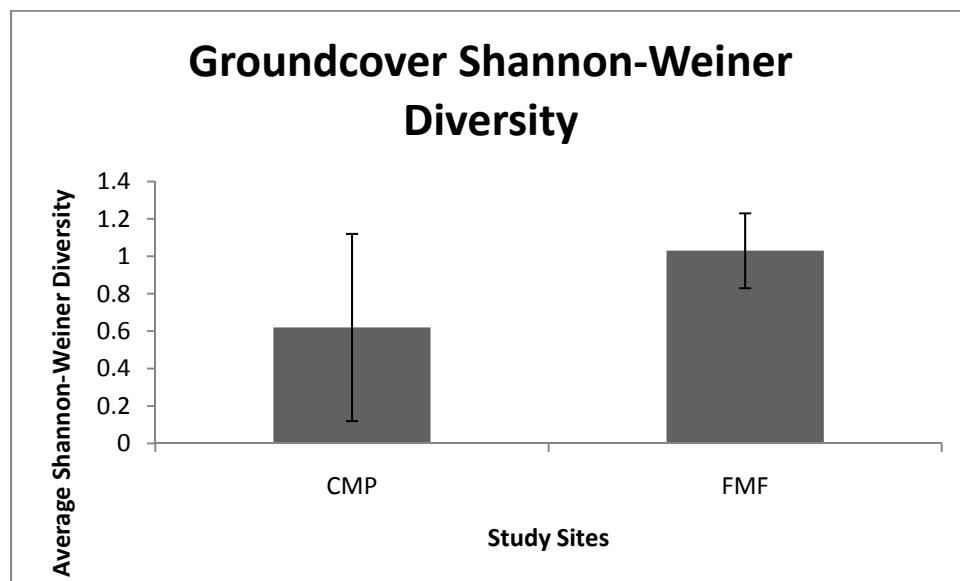


Fig. 10.- This figure displays the mean of the diversity at groundcover for CMP and FMF. The bars show the 95% confidence interval around the mean.

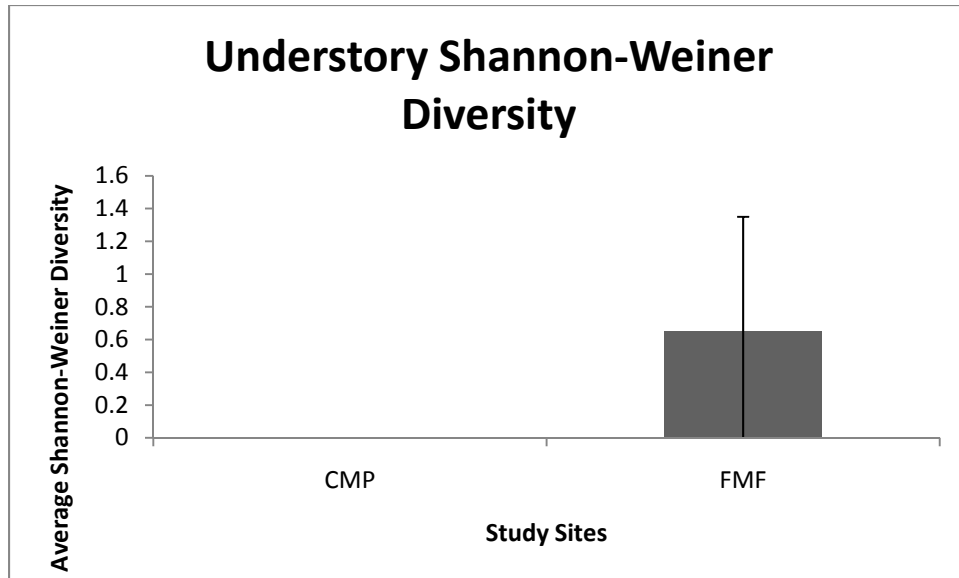


Fig. 11.- This figure displays the mean of the diversity at understory for CMP and FMF. The bars show the 95% confidence interval around the mean.

DISCUSSION AND CONCLUSION

We tested seven null hypotheses to examine the effect high densities of white-tailed deer have on vegetation. We reject our null hypotheses that there will be no significant differences between the means in preferred stem abundance at the groundcover and understory levels vertical cover density, and Shannon-Wiener Diversity Index at the understory level between CMP and FMF. We fail to reject our null hypotheses for mean total stem abundance at the groundcover and understory levels and the Shannon-Wiener Diversity Index at the groundcover levels. We found that high deer densities affect vegetation density, preferred species abundance, and understory diversity, but do not affect the overall abundance of plant species.

While collecting data at both study sites, we observed a difference in understory stems, but statistical tests did not support that there was a significant difference. This difference may be due to one plot, an outlier, in the CMP understory level. Of the total 23 stems found in the understory at CMP, this single quadrat had 22 high-bush blueberry stems (*Vaccinium*

corymbosum). A mean of 2.3 stems was a result, but if the outlier had not been present, the mean would have been closer to zero. The outlier increased the variance of the data resulting in a lower calculated t-value.

We concluded that there was a significant difference in the mean preferred stem abundance, but not in the mean total stem abundance. Deer may have over-browsed the palatable plant species. Thus, the less palatable species grew without interference. This caused the total stem abundance to be relatively similar between sites. By measuring the preferred plant species, we were able to see the effect of high deer populations on the forest vegetation composition.

A study by Carson, Banta, Royo & Kirschbaum (2005) showed the results similar to our study. The study found that preferred plants growing on high boulders, out of reach of deer, were more abundant than preferred plants where deer were able to reach them (Carson, Banta, Royo & Kirschbaum, 2005). The forest floor or groundcover contained mostly ferns or grasses, while the boulders contained plants preferred by the white-tailed deer. Our study found that at FMF, where deer were less abundant, preferred stems were more abundant. Carson, Banta, Royo & Kirschbaum (2005) found that the mean total stem abundance was not significantly different between the boulders and the forest floor. We also found that our total stem abundance was not significantly different between our sites.

There was also a significant difference for Shannon-Wiener Diversity Index at the understory level but not at the groundcover level. This could be caused by seeds sprouting in the groundcover level. The understory level shows the effect over time, meaning that it takes longer for understory plants to grow from groundcover. If the groundcover plants are eaten before they have the possibility to grow into understory plants, then there may not be an understory.

Our results suggest a difference in the composition of future forest. At both CMP and FMF we noticed that the majority of trees in the overstory consisted of oaks (*Quercus spp.*). In the future, with no young oaks in the understory level, it is possible that the overstory oaks may die and be replaced by other tree species or none at all. High deer densities might change the composition of future forests by over browsing groundcover and understory level plants that would normally mature into shrubs and trees. Red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), and American beech (*Fagus grandifolia*) were the species found on the CMP groundcover level that can mature into large trees; however, as none of these species were recorded in the understory, there is a chance that they are eaten by deer before they get a chance to grow into the overstory. If this is true, in the future there may be no overstory at all at CMP. Changes in forest composition have been studied in some Pennsylvania forests. Historically, the overstory of the Allegheny National Forest was diverse. However, the overstory level now consists of black cherry trees due to the effects of uncontrolled deer populations (Levy, 2006).

Over-browsing may also cause extirpation of many understory and groundcover level plant species that were once abundant, such as ginseng (*Panax quinquefolius*). A previous study on the ginseng species shows that the ginseng species is on the brink of extinction due to high deer densities, and has only a 57% chance of surviving this century (Levy 2006). Some species have already been extirpated from the forests due to high deer densities, especially if those plants are palatable to deer. According to a previous study, 35 plant species, including beardtongue (*Penstemon barbatus*), boneset (*Eupatorium perfoliatum*), fireweed (*Epilobium angustifolium*), monarda (*monarda fistulosa*), and sumac (*Rhus spp.*) have disappeared in some forests since 1975 (Toops, 1999). If the deer density continues to increase, we expect a decrease in plant species at CMP. We have already observed some vegetation difference between CMP and

neighboring FMF. When making visual observations at CMP, the understory level was almost non-existent. However, upon arriving at FMF, we observed that almost all vegetation was abundant.

There are many ways high densities of white-tailed deer can affect their own population as well as populations of other animals. When a population exceeds carrying capacity there are less resources like food and cover available to individuals in that population. This vegetation provides food for the deer as well as hiding places for fawns. If the deer population at CMP exceeds its resources, the population will decline. Also, fewer plants will impact populations of tree-dwelling animals by reducing available habitat (Miller & Bratton, 1992). At CMP, there were few saplings in the understory level, so when the overstory level trees die, there may be no trees to take their place. Thus, animal populations at CMP will either have to adapt to the new environment or emigrate; if not they may be extirpated (Toops, 1999).

Deer populations may be highly affected by the lack of vegetation at CMP. Less food may cause starvation and malnutrition; thus, mortality rates may increase. Natality rates may decrease from the lack of nutrition to produce fawns (Enger, Ross, & Bailey, 2007). Emigration rates will increase as deer leave, searching for palatable species not present in their current environment. This may cause a possible increase in vehicle collisions as deer unwittingly cross dangerous stretches of road, searching for food.

There are several ways we could improve our study design. When we conducted our study there were plants that we did not record because they were not inside of our quadrats. Our study recorded some plants at CMP that were not found at FMF and vice versa. This could have been caused by the experimental design and not actually on the composition of the forests. We

only recorded the plants that were present in our quadrats. In order to make our data and results more accurate, we could have increased the size of our quadrats and the sample size by using more transects and quadrats to better represent the study sites.

Another major factor in this experiment that may have affected our results is the time of the year. We did not conduct our experiment at the time where preferred plants are mostly abundant. Deer prefer herbaceous plants, which are more available for consumption in the spring. Vegetation may have been more abundant if our study was conducted during the spring (Linscinsky, Cushwa, Puglisi & Ondik 1984).

The study raised further questions. We would like to find out if deer are emigrating from CMP to access resources, if so we would like to determine if they are leaving to find food or emigrating permanently. We are also interested in comparing multiple herbivore populations to identify if the white-tailed deer population is reducing vegetation or if other animal species are impacting the vegetation. We could potentially test this by setting up a video recorder at our plot and observing if any animals besides deer come to feed on the plants in that plot or restricting deer from the study sites. A final question raised was whether the time of our study affected our results. If the study had been tested during the winter, less vegetation may have been observed at one site than another. We can test this by experimenting during different seasons. Further research on the effects of white-tailed deer on vegetation can help wildlife managers and national parks decide whether or not the deer populations may need to be controlled in order to reduce the impacts on forests, deer and other animal species, and people. At CMP they have already started controlling the white-tailed deer population. To reach their goal of reducing the density of the white-tailed deer to 8 deer/km², they have implemented lethal control measures including; sharpshooting and euthanization (National Park Service, 2008). We believe that herd reductions

will reduce the impact of deer populations on vegetation density, preferred species abundance, and understory diversity.

WORKS CITED

- Carson, W., Banta, J., Royo, A., and Kirschbaum, C. (2005). Plant Communities Growing on Boulders in the Allegheny National Forest: Evidence for Boulders as Refugia from Deer and as a Bioassay of Overbrowsing. *Natural Areas Journal*, 25, 10-16.
- Enger, E., Ross, F., and Bailey, D. (2007). *Concepts in Biology: Twelfth Edition*. Boston: McGraw Hill.
- Fergus, C. and Shope, B. (2007). White-Tailed Deer. *Wildlife Notes*. Pennsylvania Game Commission.
- Halls, L. (1984). *What Deer Eat and Why*. <http://cnrit.tamu.edu/cgrm/IRR2/1984/What%20Do%20Deer%20Eat%20and%20Why.pdf>
- Levy, S. (2006). A Plague of Deer. *BioScience*, 56(9).
- Liscinsky, S., Cushwa, C., Puglisi, M., and Ondik, M. (1984). What Do Deer Eat? *Pennsylvania Game News*.
- Miller, J. and Miller, K. (2005). *Forest Plants of the Southeast and Their Wildlife Uses*. University of Georgia Press
- Miller, S. and Bratton, S. (1992). Impacts of White-tailed Deer on Endangered and Threatened Vascular Plants. *Natural Areas Journal*, 12(2), 67-73.
- National Park Service. (2010). Catoctin Mountain Park White-tailed Deer Management Plan Frequently Asked Questions. <http://www.nps.gov/cato/naturescience/upload/Catoctin%20Mountain%20Park%20Deer%20Management%20FAQ's.pdf>
- National Park Service. (2008). Final White-Tailed Deer Management Plan/ Environmental Impact Statement. <http://parkplanning.nps.gov/document.cfm?parkId=176&projectId=10003&documentID=25018>
- Porter, W. and Underwood H. (1999). Of Elephants and Blind Men: Deer Management in the U.S. National Parks. *Ecological Applications*, 9(1), 3-9.
- Rooney, T.P. (2001). Deer Impacts on Forest Ecosystems: A North American Perspective. *Forestry*, 74 (3), 201-208.
- Sandt, Joshua L. (1997). A Brief History of Deer in Maryland and the Northeast. In *Deer as Public Goods and Public Nuisance: Issues and Policy Options in Maryland*, ed. Bruce L. Gardner, 1-3. College Park, Md: Center for Agricultural and Natural Resource Policy, October 27.
- Toops, C. (1999). By Leaps and Bounds. *National Parks*, 73(9), 30-33.

Waller, D. and Alverson, W. (1997). The White-tailed Deer: a Keystone Herbivore. *Wildlife Society Bulletin*, 25(2), 217-225.