DEER BROWSE IN THE INTERIOR FOREST OF WARWICK COUNTY PARK

Jacquelyn Arnold and Joan M. Welch
Department of Geography and Planning
West Chester University
West Chester, PA 19383

ABSTRACT: High population densities of white-tailed deer (Odocoeleus virginianus) in Pennsylvania's forested regions alter vegetation composition and regeneration by browsing young seedlings, woody shrubs and herbaceous plants. This research examined the affects of deer browse on the woody plant species of Warwick County Park's interior forest habitat by statistically testing the preference of deer to consume certain species. Six plots were randomly located within the interior forest habitat. An initial browse survey was conducted within the center four by four meters of each plot. All available and browsed stems by species were counted. A chi-squared analysis performed on the observed number of stems browsed as compared to the expected number of stems browsed by species showed that certain species were consumed in greater proportion to their availability than others. Species that were consumed less than expected included multiflora rose (Rosa multiflora), American beech (Fagus grandifolia) and maple leaf viburnum (Viburnum acerfolium). Species that were consumed more than expected included chestnut oak (Quercus prinus), red maple (Acer rubrum), and sour gum (Nyssa sylvatica). These results indicate that the pattern of woody species consumption by deer is not a random process and deer are browsing selectively. This preference towards specific species could cause a long-term change in the composition of the forest canopy tree species and a decrease in the biodiversity of the park.*

INTRODUCTION

Large populations of white-tailed deer *(Odocoeleus virginianus)* in Pennsylvania's forested regions can alter vegetation diversity and development by browsing young seedlings, woody shrubs and herbaceous plants (Tilgham, 1989). Browse is defined as the potentially palatable woody vegetation that is available to deer (Shafer, 1963). It is the new growth, represented by twig stems, eaten by deer. High deer density [greater than 18 deer per square mile (2.59 square kilometers)] affects species composition in the area they inhabit by consuming and hence destroying preferred plant species (Tilghman, 1989).

This research examines the affects of the deer population on the woody vegetation of Warwick County Park. The objective of this study is to identify the woody plants browsed by deer within an interior forest habitat and test for deer preference in selection of woody species to consume using the Chi-squared method. The consumable vegetation, deer browse, is measured by counting those stems that have been eaten by deer. The results of this study will indicate if deer are browsing selectively and demonstrate which woody plants are being browsed more than others in Warwick County Park.

The selectivity of deer to consume certain species impacts the ability of that woody plant to regenerate (grow to adult size) which has the potential to cause a significant decrease in the number of surviving adult plants. This could directly affect the biodiversity of Warwick County Park. Biodiversity reduction by deer browse causes a decrease in forest plant species richness and could possibly lead to the extirpation of certain woody species in the area.

BACKGROUND INFORMATION

Previous studies have examined the phenomenon of deer browse and its impacts on

forest ecosystems. Documentation of the selectivity of deer and their impact on forest vegetation regeneration and abundance has been recorded extensively (Bratton, 1979; Alverson et al., 1988; Tilgham, 1989; Storm et al., 1989; Cornell, 1992; deCalesta, 1994; Pomerantz and Welch, 1996).

The distinguishing characteristic of this research is that it focuses on assessment of deer browse in the interior forest habitat. In southeastern Pennsylvania, forest habitat fragmentation is a concern, and protection of interior forest habitat and associated plant and animal species is essential for maintenance of regional biodiversity (Noss and Cooperrider, 1994). While more research is required to determine specific interior forest habitat size requirements for many species, to support a diversity of viable populations of indigenous forest nesting birds and herbaceous plants, a woodland must have approximately 30 hectares of uninterrupted canopy to represent interior forest habitat. The woodlands of Warwick County Park meet and surpass that area requirement. Most studies recognize that edge habitat conditions extend from the edge of the trees into the forest up to 100 meters (Harris, 1984). The methodology for choosing sample plots included a requirement that all plots must be at least 100 meters away from the forest canopy edge.

The selectivity of deer creates stress on those species that are preferred for browse. These selective eating behaviors are demonstrated in previous studies. Conclusions arrived at by Pomerantz and Welch (1996) about Valley Forge National Park, Pennsylvania stated that deer do not browse woody plants in proportion to their availability on wood lots but rather they are selective. Generally, deer would only browse in clear-cut regions and along forest edges if a preferred species grows there in abundance (Williamson and Hirth, 1985). With the increase in deer numbers, they now browse interior forest habitat to a greater extent. A study at the Allegheny National Forest in northern Pennsylvania showed pin cherry (*Prunus pennsylvanica*), sugar maple (*Acer sachurum*), and white ash (*Fraxinus americana*) to be selected (Tilgham, 1989). Studies completed in Valley Forge National Park indicate the preference of beech *(Fagus spp.)*, maple *(Acer spp.)* and oak *(Quercus spp.)* species (Pomerantz

and Welch, 1996).

Other studies conducted in Pennsylvania hardwood forests and similar areas demonstrated the selectivity of deer for certain species. Deer show a preference for browsing pin cherry, sugar maple, red maple, white ash, tulip poplar, yellow birch *(Betula allaghaniensis)*, and black birch, and do not prefer black cherry *(Prunus serotina)*, striped maple *(Acer pennsylvanicum)*, and American beech (Marquis, 1981; Marquis and Brenneman, 1981).

Deer browse creates a variety of problems for vegetation communities. Characteristics of understory vegetation (species richness, abundance and vertical habitat structure) and associated wildlife communities are likewise affected by deer browse (deCalesta, 1992). Marquis and Brenneman (1991) concluded that white-tailed deer were a significant negative influence affecting regeneration of commercial northern hardwoods in the mid-Atlantic states by consuming young seedlings.

Successful generation of hemlock *(Tsuga canadensis)* in northern Wisconsin was inhibited by deer through the consumption of seedlings in the understory (Alverson et al., 1988). Shade tolerant, canopy species were not found in the understory and hence were not regenerating in Valley Forge National Historic Park (Pomerantz and Welch, 1996). The interaction of deer browse impacts and forest health factors in northwestern Pennsylvania is creating the potential for old growth forests with beech, hemlock, and sugar maple overstories to be biologically succeeded by forests characterized by striped maple (*Acer pennsylvanicum*) and declining beech overstories (deCalesta, 1992).

STUDY AREA

The study takes place in Warwick County Park located in northern Chester County in the southeast region of Pennsylvania (Figure 1). The park encompasses approximately 178 hectares of which the core is a mature hardwood forest comprised of a north-facing rocky slope at the base of which is French Creek and associated bottomland/wetland habitat. The forest has regenerated from servicing a charcoal industry that once supplied numerous iron furnaces in the vicinity
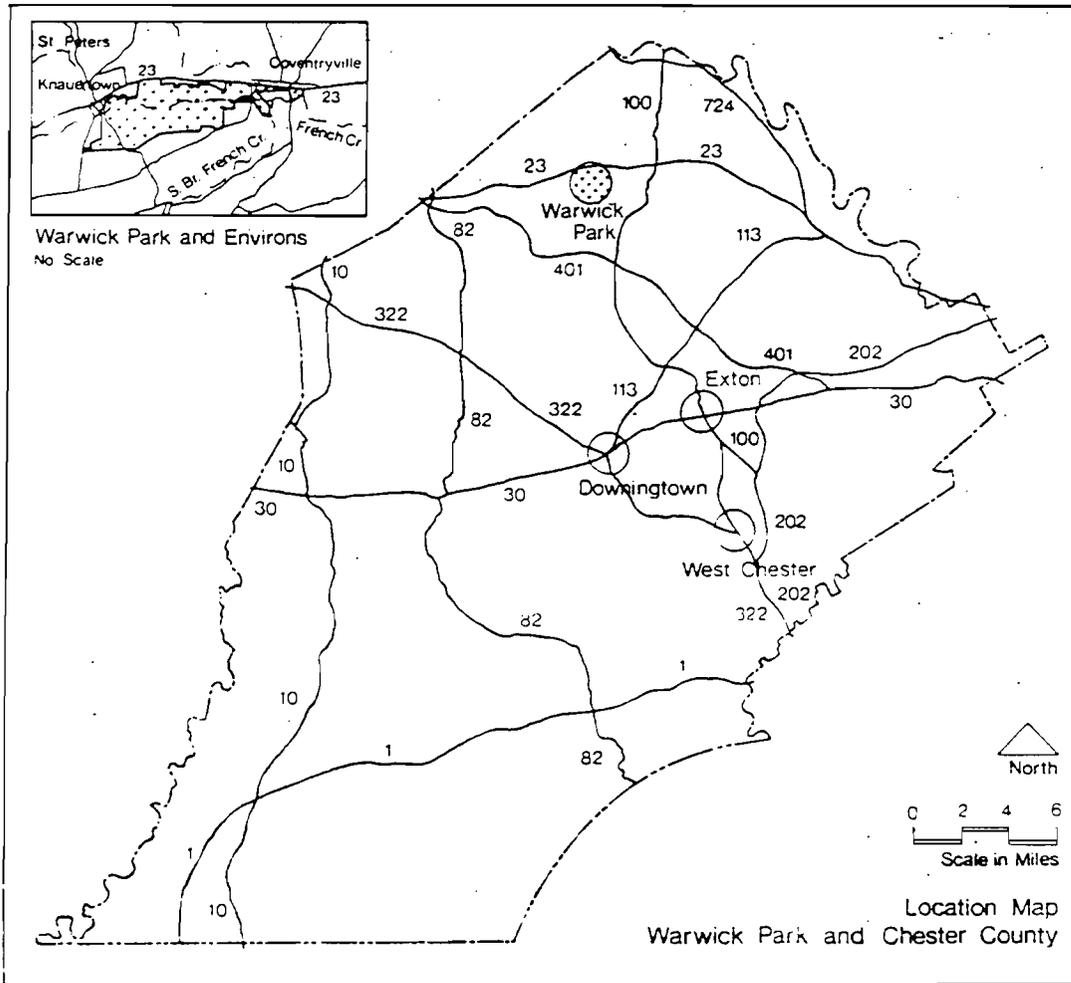
Figure 1   Warwick Park and Chester County.

during the 1700s and 1800s (Vanderwerff, 1993). The ages of large trees cored during the study were approximately 95 years. Canopy species surveyed at the six deer exclosure sites at Warwick County Park included 17 tree species. According to frequency of occurrence, the top seven species in descending order of importance that were represented by more than two individuals included: black birch *(Betula lenta)*, American beech *(Fagus grandifolia)*, red maple *(Acer rubrum)*, tulip poplar *(Liriodendron tulipifera)*, red oak *(Quercus rubra)*, sour gum *(Nyssa sylvatica)*, and white ash *(Fraxinus americana)*. The remaining species were

represented by one or two individuals and included: Norway maple *(Acer platanoides)*, sugar maple *(Acer saccharum)*, ironwood *(Carpinus caroliniana)*, smooth alder *(Alnus serrulata)*, white oak *(Quercus alba)*, black oak *(Quercus velutina)*, chestnut oak *(Quercus prinus)*, American chestnut *(Castanea dentata)*, dogwood *(Cornus florida)*, and poplar *(Populus grandidentata)*. The Warwick County Park forest is a good representative of a Pennsylvanian hardwood forest, therefore allowing guidelines for past deer browse studies to be used (Vanderwerff, 1993).

From general observation, Warwick County Park Superintendent Owen Prusack noticed minimal woody species regeneration in the understory (personal communication, 1996). The park also carried out controlled deer hunts to combat the perceived problem of understory species impoverishment and impaired forest regeneration from heavy deer browse. The objectives of the research presented herein were to document and investigate the effects of deer browse on the interior forest habitat of Warwick County Park to guide forest management plans. The study of deer browse in Warwick County Park allows for future recommendations for forest protection. Lowering the deer populations to a level where they could be maintained for several years would allow the forests to develop an understory with a diverse community of seedlings, shrubs and herbaceous plants (Tilgham, 1989).

METHODOLOGY

Deer browse is measured on a four by four meter plot located in the center of six randomly selected plots. To sample the forested area, six randomly selected plots were sampled for tree species composition (individuals with a diameter at breast height greater than or equal to five centimeters), and 20 by 20 meter fenced exclosures were built. Deer exclosure size of 20 by 20 meters was selected according to minimum sample area to represent the temperate forest overstory community, and within the deer exclosure, the center four by four meters were selected for deer browse evaluation according to minimum sample area to represent the temperate forest undergrowth vegetation community (Barbour et al., 1987). There are four plots in the upland area and two in the lowland area. To randomly select the sites for these areas, a numbered grid was placed over a map of the forest (with a 100 meter edge buffer to exclude edge habitat), and a random numbers table was used to generate coordinates. The location in the park of these randomly selected plots was established using a Global Positioning System. These six exclosures will allow for future measurements of the enclosed woody vegetation in

the absence of deer.

The four by four meter center plots were located using a compass and a measuring tape. This follows the guidelines of Cypher and Yahner (1985). To avoid any potential problems in the research design, some suggestions made by previous studies were followed. Rutherford (1979) found that available browse is restricted to the vegetation from the ground level to 1.8 meters above ground. Therefore all of the stems that were counted in this center plot were 1.8 meters or below. Plot number, species, number of stems browsed and number of stems available were recorded at each site. Since the sites represent a sample of the total population of woody species in Warwick County Park's interior forest, the data were aggregated per plant species.

To test for a significant relationship between stems browsed and preference of deer towards certain woody species, a chi-squared (x^2) analysis was employed. This test compares the distribution of the observed number of stems browsed to an expected or theoretical frequency distribution of stems browsed. Results indicate whether the observed distribution of stems browsed by species is significantly different from a uniform or random distribution of stems browsed. The null hypothesis states that the browse of woody species found in Warwick County Park study plots does not differ significantly from a uniform or random frequency distribution. The alternate hypothesis states that the browse of woody species does differ significantly from the uniform or random frequency distribution.

RESULTS

Woody plant species were identified in six plots. For each species, both total amount of stems available to deer and total stems browsed by deer were counted (see Table 1). The available stems in the plots were dominated by American beech, black birch, blueberry *(Vaccinium spp.)*, maple leaf viburnum *(Viburnum acerfolium)*, mountain laurel *(Kalmia latifolia)* and ironwood. To determine the proportion of stems of each species that had been browsed, the number of stems browsed was divided

Table 1 Summary of Woody Plant Species Identified at the Study Sites of Warwick County Park 1996.

Browsed Species	# of plots present on	Total # of plants	# of stems available	# of stems browsed	Proportional utilization
Beech	3	12	698	292	0.42
Black Birch	3	4	760	199	0.26
Black Cherry	2	25	243	151	0.62
Blackberry	2	2	3	1	0.33
Blueberry	5	93	3615	1877	0.52
Chestnut Oak	2	14	136	100	0.74
Greenbriar	1	1	22	13	0.59
Maple Leaf Viburnum	5	343	5009	2566	0.51
Mockernut Hickory	1	10	75	51	0.68
Azalea	1	64	794	573	0.72
Multiflora Rose	1	10	18	0	0
Ironwood	1	3	2211	484	0.21
Raspberry	1	25	54	14	0.26
Red Maple	4	30	272	172	0.63
Red Oak	1	1	25	17	0.68
Smooth Alder	1	5	23	7	0.3
Sour Gum	2	13	61	34	0.56
unknown	4	7	65	35	0.54
White Ash	1	2	28	6	0.21

by the total number of stems available by species (see Table 1).

To test for browse selectivity by deer for woody species, a chi-squared analysis was performed. Chi-square is a method to determine if a significant difference exists between a set of observed frequencies and the corresponding expected frequencies. In this case, it compares the counted or observed number of stems browsed to an expected number of stems browsed. To ensure a significant sample size for each species used in the chi-squared calculations, those species having less than five identified plants across all plots were excluded from the analysis.

Table 2 illustrates the calculations used in the chi-squared analysis. The number of stems available for each species is the total count of stems browsed and not browsed. The proportion of total stems available is determined by dividing the stems available for a species by the total number of stems for all species. The observed number of stems browsed is the number of browsed stems counted in

the field for each species. The expected number of stems browsed is determined by multiplying the proportion of total stems available for each species by the total amount of stems browsed for all species. For example, American beech stems represent a proportion of 0.0635 of all species, and when this is multiplied with 5837, an expected value of 371 is obtained (see Table 2).

The calculated chi-square value was 116.98 with 11 degrees of freedom. The critical chi-square number is 19.675. Therefore the null hypothesis is rejected at $\alpha = 0.05$ because the calculated chi-square value of 116.98 is greater than 19.675. The alternate hypothesis that the woody species population does not fit the uniform or expected frequency distribution is accepted. Deer do not browse woody plants in proportion to their availability in Warwick County park. Deer browse the woody species selectively.

This selectivity of deer towards certain species is shown by the difference in the number of observed stems browsed and the expected number

Table 2 The Availability of Woody Species in Warwick County Park and the Chi-squared Calculation Input Values.

Browsed Species	# of stems available	Proportion of total stems available	Observed # of stems browsed	Expected # of stems browsed
Beech	698	0.0635	292	371
Black Cherry	243	0.0221	151	129
Blueberry	3615	0.3287	1877	1919
Chestnut Oak	136	0.0124	100	73
Maple Leaf Vib.	5009	0.4554	2566	2658
Mockernut Hickory	75	0.0068	51	40
Azalea	794	0.0722	573	421
Multiflora Rose	18	0.0016	0	9
Raspberry	54	0.005	14	29
Red Maple	272	0.0247	172	144
Smooth Alder	23	0.0021	7	12
Sour Gum	61	0.0055	34	32
Total:	10998	1.0	5837	5837

of stems browsed (see Table 2). Six species were used less than expected: beech, blueberry, maple leaf viburnum, multiflora rose *(Rosa multiflora)*, raspberry *(Vaccininum spp.)*, and smooth alder. Some of these species had a high number of stems browsed but they were still less than expected. Six species had a greater number of stems browsed than expected: black cherry, chestnut oak, mockernut hickory *(Carya tomentosa)*, mountain laurel, red maple, and sour gum.

CONCLUSIONS

Large populations of white-tailed deer are altering the understory woody species in the interior forest of Warwick County Park. The chi-square test employed demonstrates that deer are browsing woody species selectively in the interior forest of Warwick County and are not browsing plants in proportion to their availability. By consuming the young stems that are available to them, they are impairing the regeneration of some woody species.

Deer preference towards certain plants may be changing the species composition of the interior forest.

Results from this study closely follows those documented by previous researchers. Bratton (1979), Marquis and Breneman (1981), Redding (1987), Alverson et al. (1988), Tilgham (1989), Storm et al. (1989), Cornell (1992), deCalesta (1994), and Pomerantz and Welch (1996), demonstrated the preference of deer towards certain woody species. Studies have listed heavy use of species such as red maple and sour gum because they were browsed more than expected thereby indicating preference (Marquis, 1974; Tilgham, 1989; Pomerantz and Welch, 1996). Chestnut oak has also been observed as a preferred species in Valley Forge National Historic Park (Pomerantz and Welch, 1996). The lower number of stems browsed than expected for maple leaf viburnum in Warwick County Park does not follow results from previous studies. This could be due to the extreme abundance of stems available to deer.

Of the seventeen tree species identified in the six 20 by 20 meter sample plots, eight are present as woody plants in the understory (beech,

black birch, chestnut oak, red maple, red oak, smooth alder, and sour gum), but only five are present in signficant enough numbers to be included in the chi-squared analysis (beech, chestnut oak, red maple, smooth alder, and sour gum). Of these five, chestnut oak, red maple and sour gum were browsed more than expected in keeping with past studies on preferred browse of deer. Beech seedlings are extensively browsed (proportional utlization 0.42) but less than expected because deer do not prefer to browse beech seedlings. The fact that deer are browsing extensively on beech and black cheery seedlings, another less preferred species, may indicate that preferred species resources may already have been exhausted (Tilgham, 1989; Marquis, 1981; Marquis and Brenneman, 1981).

Although some plants have been browsed more than others, a hierarchical arrangement of preferred plants cannot be determined from this study. Deer browse varies regionally and seasonally; it depends on the plants available and their numbers, and deer densities (Pomerantz and Welch, 1996). In an attempt to evaluate the long-term impacts of high numbers of deer and their browsing behavior on the interior forest habitat of Warwick County Park, the study will continue to compare understory woody species composition within the deer exclosures to that of control sites outside the deer exclosures. The study will also evaluate the relationship between overstory canopy tree species and those regenerating in the understory both from inside and outside of the deer exclosures.

ACKNOWLEDGEMENTS

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