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White-tail Deer Browsing on Tree Saplings within Properties of the French Creek Valley Conservancy

A Report Submitted to the French Creek Valley Conservancy

Katherine K. Brozell, Editor
Olivia E. Maack, Editor
Sebastian M. McRae, Editor
Luella L. Curtis
Sarah Degrendel
Colleen S. Flynn
Lucas J. Gilmore
Alexandra N. Graf
Charles A. Harris
Matthew J. Heasley
Hannah O. Heutsche
Sarah L. Mayer
Liam S. McCann
Jordan T. Rawls
Sarah I. Schmidt
Faythe Schulte
Kaitlyn W. Thompson
Timothy P. Weighart
Richard D. Bowden

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Abstract

White-tail deer at high population densities threaten forest health by browsing extensively on tree saplings, which can limit tree regeneration and eliminate essential understory habitat for other forest species. In northwestern Pennsylvania, a century of agricultural abandonment, forest harvesting, predator extirpation, and strict regulation of deer hunting has created ideal conditions for deer populations to expand and for overbrowsing to occur. Land conservation organizations can find it challenging to promote biodiversity in forests subject to intense browsing. The purpose of this study was to determine the extent to which white-tail deer browsing is impeding forest sapling growth on three properties owned by the French Creek Valley Conservancy (FCVC). We examined sapling heights and terminal bud browsing occurrences for the period 2016-2020. We found a consistent sapling height of approximately 50 cm at all three properties, regardless of how many times the saplings were browsed. Most saplings were browsed at least twice between 2016 and 2020, and the probability of a sapling remaining unbrowsed for five consecutive years was less than 10%. This indicates that under high browsing pressure, tree saplings remain within the reach of deer, allowing deer to browse repeatedly and cause stunted sapling growth. Reduced growth threatens creation of a forest understory and can limit forest regrowth if overstory trees are removed due to natural causes or forest management activities. We recommend that hunter participation be encouraged on FCVC properties to deter higher populations of deer and mitigate effects of excessive browsing on their lands. Using deer exclosures or tree tubes may also be necessary to protect saplings until they grow beyond the reach of deer.

Keywords: White-tailed deer, browsing, forest, saplings, French Creek Valley Conservancy

Introduction

Elevated white-tail deer (*Odocoileus virginianus*) populations can reduce long-term forest health by reducing stand regeneration (Tilghman 1989) and diversity (Kittredge and Ashton 1995), limiting understory richness due to selective herbivory (Horsley et al. 2003, Randall and Walters

2011), and increasing dominance of non-preferred species (Horsley et al. 2003). The severity of these impacts of browsing is dependent upon the density of white-tail deer populations (Tilghman 1989), and can have far-reaching effects on other forest species, such as ground and intermediate-canopy nesting songbirds (DeCalesta 1994). As a result, deer browsing intensity needs to be considered in efforts to manage forest lands for long-term forest health.

Interactions between forests and deer is driven by the history of forest use. In the late 19th century, Pennsylvania's forests were clear cut extensively for timber, the chemical wood industry, and to make room for agriculture (Whitney 1990). Market hunting and loss of forested habitat and food sources resulted in a near-complete removal of deer from Pennsylvania (Whitney 1990) However, widespread abandonment and subsequent reforestation of marginal farmland in the 20th century created ideal conditions for deer (Whitney and DeCant 2003), which were brought back to Pennsylvania by the Pennsylvania Game Commission (Kosack 1995). In addition, implementation of hunting regulations, extirpation of natural predators, and abundant food from agricultural sources enabled deer densities to increase dramatically (Redding 1995), often exceeding the carrying capacity of regrown forests. As trees grew into the upper canopy, forest floor-level vegetation became limited by light and browsing, resulting in chronic browsing pressure on the deer's primary winter forage: young tree saplings. Chronic browsing of terminal buds on young saplings reduces sapling survival and can stunt growth over a tree's lifetime (Holm et al. 2013). The mid-Atlantic region, which includes Pennsylvania, shows severe impacts of herbivory-stressed vegetation, with nearly 80% of all forest land showing moderate to severe browsing impacts (McWilliams et al. 2018). Sustained elevation of deer densities resulting from a lack of effective population control has both ecological and economic consequences; reduced stand regeneration from deer browsing may reduce the economic viability of tree harvesting in privately-owned forests (Tilghman 1989), which make up 70% of Pennsylvania's forested land (USDA Forest Service 2019).

Maintaining a balance between deer populations and forest vegetation is challenging. Deer populations were historically kept in check by predators (Redding 1995); however, the major predators of deer (wolves, cougars) are no longer present in Pennsylvania (Ripple et al. 2010). Hunting is now the major management tool available to control deer (McDonald et al. 2007), but changes in public attitudes towards hunting and declines in the numbers of licensed hunters (U.S. Fish and Wildlife Service and U.S Census Bureau 2016), are hampering human control of deer populations. Further complicating the issue is that hunting regulations in most states, including Pennsylvania, are set at the state level, giving land owners or managers few options to control deer in their locality. Controlled hunts are controversial and costly (Deorr et al. 2001) and state-wide programs that target specific land areas (e.g, Pennsylvania Deer Management Assistance Program) typically still rely upon the hunting public. Balancing deer and forest integrity can be especially vexing for conservation land trusts, whose management priorities may differ substantially from private landowners seeking to profit from periodic timber harvesting. According to the Pennsylvania Land Trust Association (Pennsylvania Land Trust Association 2020), a land trust is an organization that acquires land through purchase or donation for a variety of conservation

purposes, such as wildlife habitat protection or farmland preservation. This wide range of conservation purposes can create a diversity of suggested management approaches due to the public's sometimes divergent or even opposing philosophical views on conservation. Hunting, for example, is embraced by the National Audubon Society as a means to keep deer populations in balance with forest resources (Kocieniewski 2005), but is opposed by many animal advocacy groups, such as the Humane Society of the United States and the American Society for the Prevention of Cruelty to Animals (HSUS 2020, ASPCA 2020). In light of continuing conversations about methods for controlling deer populations, assessments of the current extent of browsing are critical first steps in mitigating effects of excessive browsing on preserved lands.

The French Creek Valley Conservancy (FCVC) is a land trust based in northwestern Pennsylvania, whose mission is to protect the water quality, natural habitat, biological diversity and recreational opportunities of the French Creek watershed (FCVC 2019). Ensuring adequate forest regeneration is an important part of the Conservancy's goal of maintaining or enhancing biodiversity. The FCVC recognizes that deer browsing threatens forest regeneration, but the extent of deer browsing on their properties is unknown. Information about current browsing rates will help inform the Conservancy about potential effects on forest regeneration, and inform management practices that will enhance biodiversity.

The purpose of this study was to quantify the rate of browsing on tree saplings by white-tail deer on several FCVC properties. We hypothesized that deer browsing was prevalent on the properties, and that the rates of browsing pose a threat to tree saplings.

Study Areas

The French Creek Valley is located in northwestern Pennsylvania, which has a temperate continental climate and predominantly deciduous hardwood forests with intermittent stands of hemlock and pine. Much of the region was used historically for agriculture beginning in the mid-19th century, until agriculture began to decline in the mid-20th century. Lands rebounding from agricultural use are dominated by early-successional tree species. The average annual precipitation of the region is 112.5 cm and the average annual temperature is 8.7^{o}C (U.S. Climate Data 2020). Precipitation is relatively evenly distributed throughout the year, and the region has an approximate four-month growing season and approximately four months of snow cover.

We selected three properties belonging to the French Creek Valley Conservancy, all located in the French Creek watershed: Mammoth Run, Raup Wildlife Sanctuary, and Lew's Land (Fig. 1, Table 1). The forest stands we examined were characterized by closed canopies consisting largely of red maple (*Acer rubrum*), black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), and American beech (*Fagus grandifolia*). The sites were located in both semi-urban and rural environments, 12-36 ha in size and consisted of similarly aged second-growth forest on land that was previously used for agriculture. Portions of Lew's Land had also been used as a gravel quarry.

Figure 1. Location of French Creek Valley Conservancy properties used for deer browse study.

Table 1. Study site characteristics for Mammoth Run, Raup Wildlife Sanctuary and Lew's Land.

Site	Area (ha)	Aspect	Surrounding Landscape	Land Use History and Description
Mammoth Run	34.8	SE	Residential/ Agriculture	Prior agricultural use, tree harvesting.
Raup Wildlife Sanctuary	12.5	S	Forest/ Agriculture Mosaic	Prior agriculture use.
Lew's Land	19.4	NE	Residential/ Developed	Part of the area had been used for gravel extraction; a power transmission line extends through the property.

Methods

We sampled the three sites in February and March, 2020. At each site, we established two (Mammoth Run) or three (Raup Wildlife Sanctuary, Lew's Landing) 50m x 50m plots. Plots were selected to be representative of each site. Within each plot, we randomly chose 12 subplots, for sampling sapling heights and browsing history from 2016-2020 (5 years). We sampled the 20 live saplings that were nearest to the subplot center; all saplings were selected to be less than two meters in height, on the assumption that saplings taller than two meters would not be adversely affected by browsing (Sullivan et al. 2020). To determine the browsing frequency of each sapling, we first looked to see if the current terminal bud had been browsed. We then looked for evidence of browsing in the terminal buds in the current and the four previous years. Browsing could be determined if a previous terminal branch appears to have been removed and lateral branches had assumed dominance. We did not identify the species of the saplings.

Results

Sapling height and deer browsing intensity differed among the three sites ($p<0.05$). Saplings were shortest at Mammoth Run, and were 12% and 23% taller at Lew's Landing and Raup Wildlife Sanctuary, respectively. Minimum and maximum sapling heights were similar across the sites (Table 2).

The annual browsing rate (percentage of saplings browsed in a given year) varied over the five years at each site (Table 3), and differed among sites ($p<0.001$). Browsing rates were highest at Mammoth Run (49.2 ± 2.2 % of saplings) followed by Raup Wildlife Sanctuary and Lew's Land.

Table 2. Mean, minimum, and maximum heights of tree saplings for Mammoth Run, Raup Wildlife Sanctuary and Lew's Land. SE = Standard Error.

	Height (cm)				
Site	x	SE	Min	Max	n
Mammoth Run	45.5	1.3	8	190	440
Raup Wildlife Sanctuary	56.1	1.1	9	187	720
Lew's Land	51.1	1.1	11	196	720

Table 3. Sapling browsing rates for years 2016-2020 at Mammoth Run, Raup Wildlife Sanctuary and Lew's Land. SE = Standard Error.

Site	2016	2017	2018	2019	2020	x	SE
Mammoth Run	55.5	48.0	53.0	44.2	45.4	49.2	2.2
Raup Wildlife Refuge	39.2	46.8	42.5	43.6	38.2	42.0	1.5
Lew's Land	43.3	44.7	38.5	34.0	30.6	38.2	2.7

Annual browsing rates varied from a low of 30.6% at Lew's Land in 2016 to 55.5% at Mammoth Run in 2020. Most saplings were browsed more than once over the five-year period (Table 4.) A frequency distribution showed that over the five years, few saplings were not browsed, and few saplings were browsed all five years (Fig. 2). Most were browsed one to three times at all three sites.

Using the annual rates of browsing, we estimated the probability of a sapling remaining unbrowsed for five consecutive years. This was calculated by multiplying together the unbrowsed rates (100% - browsed rate, expressed as a proportion) for the five years. The likelihood of a sapling being unbrowsed was 3.3% at Mammoth Run, 6.5% at Raup Wildlife Refuge, and 8.8% at Lew's Land.

We found that browsing intensity did not affect tree sapling height. There was no significant difference in sapling heights among the number of years that a sapling was browsed at any of the sites (Fig. 3). Mean sapling heights for all three properties were approximately 50cm, regardless of how many years the saplings were browsed.

Table 4. Number of times that saplings were browsed from 2016-2020 at Mammoth Run, Raup Wildlife Sanctuary and Lew's Land. SE = Standard Error.

	Times Browsed (2016-2020)		
Site	**x**	**SE**	**n**
Mammoth Run	2.45	0.06	440
Raup Wildlife Refuge	2.09	0.05	720
Lew's Land	1.86	0.05	720

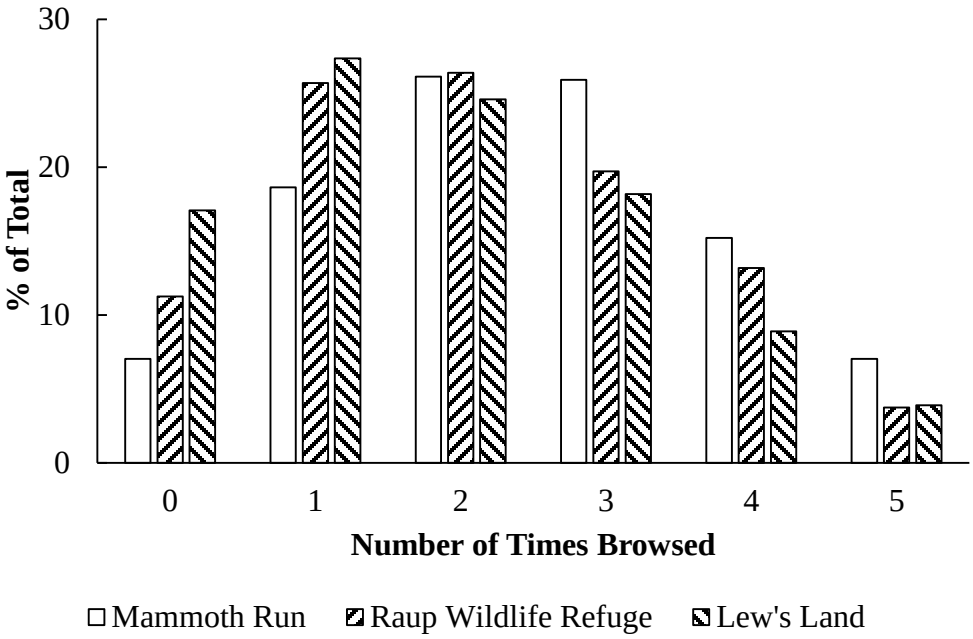

Figure 2. Frequency distribution of saplings browsed 0 to 5 times from 2016 to 2020 at Mammoth Run, Raup Wildlife Sanctuary and Lew's Land.

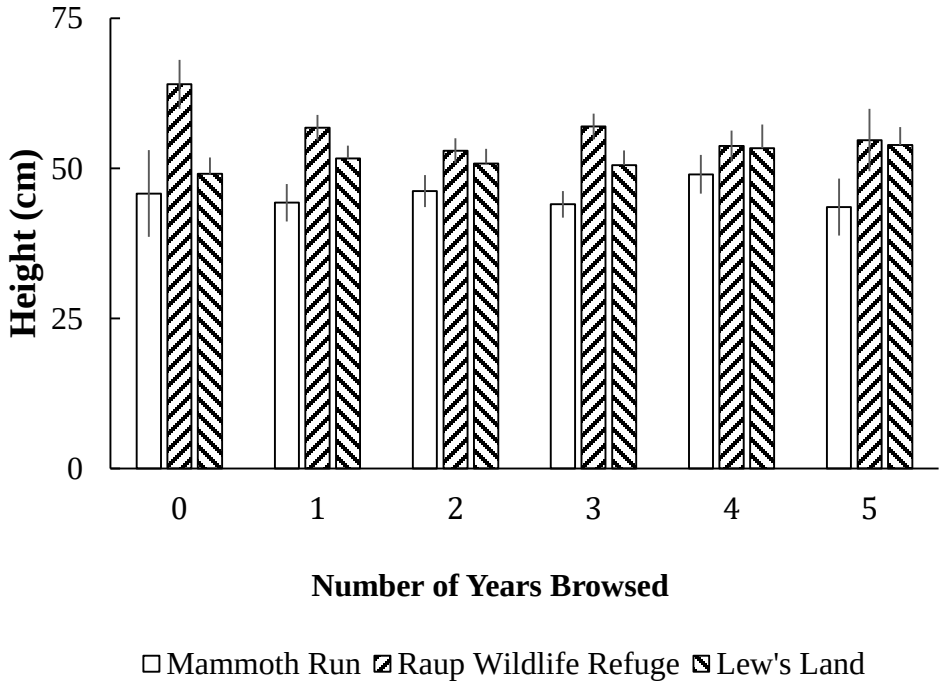

Figure 3. Sapling heights (±SE) versus the number of years browsed (2016-2020) at Mammoth Run, Raup Wildlife Sanctuary and Lew's Land.

Discussion and Recommendations

At the three sites, extensive browsing has had a noticeable effect on sapling height. With some variation, saplings averaged only 50 cm in height, remaining well within the 2 m height range browsed by deer (Sullivan et al. 2020). Given that unbrowsed saplings were not taller than browsed saplings, it appears that saplings are not generally browsed until they reach a height of 50 cm, after which they are subject to browsing. This would correspond to approximate snow depth during winter, when browsing of stems is most likely to occur. When saplings grow into the browsing range, repeated browsing causes saplings to remain at approximately 50cm in height, suggesting a severely limited ability for development of a vigorous understory tree community. The mean sapling height of 50 cm at our sites is consistent with those from other studies investigating the browsing impact of high deer density (Tilghman 1989, Kittredge and Ashton 1995), suggesting that deer densities are elevated on FCVC's properties. Diverse forests have a mixture of tree ages and heights because regeneration is constantly occurring; the lack of tree saplings growing taller than two meters means that adequate regeneration is not occurring, and suggests a trend of severe overbrowsing in the area (Whitney 1984, Horsley et al. 2003). Sapling growth is significantly more vigorous when deer are absent or reduced (Tilghman 1989).

The challenge of producing a viable understory is emphasized by the finding that the probability of a sapling being unbrowsed for five consecutive years ranged from three to ten percent; nine out of ten saplings would have thus experienced stunted growth between 2016 and 2020. Most saplings were browsed at least twice in this period; the lowest annual browsing rate was never less than 30%. These results are consistent with other browse studies in this area. Across several vegetation types at the Allegheny College Bousson Experimental Forest, located approximately 10 km southeast of Meadville, more than 80% of all saplings were browsed at least twice (Nageotte 2019). Similarly, across several forested sites in Crawford and Mercer County, from 70.2 % to 93.3 % of saplings were browsed (Baker 2020).

High deer densities reduce woody vegetation in the intermediate canopy, leading to the loss of forest species that depend on this habitat (deCalesta 1994). Overbrowsing also alters tree composition. In the nearby Allegheny National Forest, the heights of birch, red maple and American beech seedlings were reduced at higher deer densities (Horsley et al. 2003). Black cherry and pin cherry, however, remained largely unaffected (Horsley et al. 2003), likely because they are not preferred browse species. High sapling mortality in preferred browse species results in a forest composition with greater numbers of less desirable species (Tremblay et al. 2007), a legacy that can exist for at least two decades (Nuttle et al. 2014). This deer browsing preference, if coupled with differing tree species compositions, may have contributed to variation in sapling height and browsing rates across the three sites (Tremblay et al. 2007). However, because we did not record sapling species, our data do not show a relationship between tree species and browsing. Variation in browsing rates across the five years may also be attributed to variations in deer density (Tilghman 1989) and snow cover (Morrison et al. 2002) during the 2016-2020 timeframe; again, we did not collect data on deer populations or snow depths, so this attribution is speculative. Future research on the influence of snowpack reductions from changing regional climates on the intensity

and selectiveness of deer browsing could prove valuable to forest conservation efforts in northwestern Pennsylvania.

The low height of saplings and high browsing frequency indicates the necessity of lowering deer densities to enable increased regeneration and greater diversity in tree species and ages, which would be desirable to maintain the ecological, recreational, and economic values of FCVC properties. Even if deer densities are reduced, overstory trees (Tanentzap et al. 2011) and understory vegetation (Boulanger et al. 2015) may be slow to regenerate as the ecosystem recovers, so we suggest action be taken as soon as possible to reduce deer densities and allow for forest recovery. Accordingly, allowing hunting on selected FCVC properties, as the conservancy currently does, is a cost-effective means to assist in controlling deer impacts (Pennsylvania Game Commission 2009). The conservancy may consider participating in the Pennsylvania Game Commission's Deer Management Assistance Program (DMAP), which will allow additional hunting on qualified properties. If desired, the FCVC may wish to consider allowing only late season archery hunting during DMAP periods so that noise from firearms does not interfere with other recreational activities on the properties. However, because of the relatively small size of the FCVC properties in comparison to surrounding lands, and the high mobility of deer herds, actions taken on individual properties have a limited ability to influence deer density on the landscape scale. In the Adirondack Mountains (NY), deer have a home range of 130-225 ha (Tierson et al. 1985), an order of magnitude greater than the size of the sites that we examined. In addition, hunting alters deer behavior (Kilpatrick and Lima 1999, Root et al. 1988), thus deer move into areas with less activity, at least temporarily. Coinciding with this fact, DMAP permits offered on FCVC properties could result in increased hunter participation while not necessarily increasing the amount of deer harvested from the property. The increase in human activity would pressure the deer out of the properties during the crucial time at which saplings are browsed. A further compounding factor is that the hunting population is in decline both nationally (Winkler and Warnke 2013) and in Pennsylvania, and the ability of hunting alone to control deer populations is considered to be unlikely (Brown et al. 2000). These statewide and national declines in hunter participation may not yet be playing out entirely here in northwestern Pennsylvania, as indicated by the fact that antlerless deer permits sell out routinely for this area. Nonetheless, the conservancy could consider using temporary exclosures or tree tubes as an additional means to protect saplings from deer browsing. Exclosures are effective in promoting desirable saplings and herbaceous plants (Parker et al. 2020, Shafer et al. 1961) and plastic tree tubes placed on individual saplings can effectively protect saplings from browsing (Marquis 1977). Additionally, monitoring vegetation growth and evidence of browsing through visual assessments on FCVC properties will be important to assess long-term sapling growth and forest composition.

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