COMPARISON OF DEER BROWSING INTENSITY OF TREE SEEDLINGS IN OPEN AND FENCED PLOTS IN SOUTHERN ONTARIO, CANADA

By

Mackenzie Jemmett

1132915

Faculty of Natural Resources Management

Lakehead University

April 2024

COMPARISON OF DEER BROWSING INTENSITY OF TREE SEEDLINGS IN OPEN AND FENCED PLOTS IN SOUTHERN ONTARIO, CANADA

By

Mackenzie Jemmett

An Undergraduate Thesis Submitted in

Partial Fulfillment of the Requirements for the

Degree of Honours Bachelor of Science in Forestry

Faculty of Natural Resource Management

Lakehead University

April 2024

Dr. Ashley Thomson
Major Advisor

Dr. Brian McLaren
Second Reader

LIBRARY RIGHTS

STATEMENT

Signature: ______________________________

Date: 2024/04/23

A CAUTION TO THE READER

This HBScF thesis has been through a semi-formal process of review and comment by a least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of either the thesis supervisor or the faculty of Lakehead University.

ABSTRACT

This study examined the intensity of browsing by white-tailed deer *(Odocoileus virginianus)* on tree seedling growth in wildlife management unit (WMU) 83B. The study was conducted in an island ecosystem that has regular browsing with a large white-tailed deer population. I used exclusion plots to compare the percent browse and tree seedling height between open and fenced plots located in an open area plantation and a bush area plantation with partial shade. One plot from each area had a constructed electrical fence to control and measure the intensity of the deer browsing on the plots. Species used for observation were the following: *Pinus strobus* (eastern white pine) and *Acer freemanii* (autumn blaze maple). Observations of regenerating species in the plots allowed for examining deer browsing intensity and seedling growth effected by white-tailed deer in an island ecosystem. Fenced plots experienced no disruptions to growth and non-fenced plots showed immediate effects to growth due to high densities of white-tailed deer. Deciduous seedlings were browsed more than coniferous seedlings, although autumn blaze maples showed resilience to browsing. My results suggest that exclusion fencing similar to that used here can be an effective means of preventing deer browse and may be useful in areas where intensive deer browsing otherwise greatly impedes seedling growth.

Keywords: white-tailed deer *(Odocoileus virginianus)*, island populations, island ecosystems, browsing, forest regeneration, browse intensity, tree growth, exclusion fencing.

CONTENTS

TABLES

FIGURES

ACKNOWLEDGMENTS

I thank Dr. Ashley Thomson for being my supervisor and providing guidance during the research, the writing process, advice on further steps, and contributing to my knowledge of forest species. I am grateful to Dr. Brian McLaren for being my second reader and giving advice about white-tailed deer and browsing tree species. I would like to express my appreciation for the assistance of Wyatt Hendrick in organizing trips to the study area, sharing valuable information, gathering equipment, setting up fences and trail cameras, and support. Lastly, I thank the private not-for-profit organization staff and members for providing accommodation, land use, equipment, documents, and support throughout the research.

INTRODUCTION

High densities of large herbivores may significantly impact forest composition and regeneration through intensive browsing of palatable tree species (Borowski et al. 2021). Browsing is a common interaction that occurs among forest species and herbivores, which can be defined as consuming parts of woody plants including buds, twigs, and leaves (Russell 2020). Impacts of large herbivore browsing are variable and may include reduced understory species richness, reduced seedling growth, and forest regeneration failure (Akash et al. 2022). Thus, the success of forest regeneration is often linked to browsing pressure from large herbivores such as white-tailed deer (*Odocoileus virginianus).*

White-tailed deer is a large mammal widely distributed in North America and occurs in the southern parts of most provinces in Canada (OMNR 2024). The preferred habitat of white-tailed deer is a mixture of open fields and woodlands. White-tailed deer preferentially feed on young shoots of deciduous trees and shrubs (Jackson & Finley 2021; Akashi et al. 2022). Preferred browse species include maple (*Acer)* and Oak *(Quercus)*, although coniferous species such as cedar (*Thuja)* and pine (*Pinus)* may be consumed when preferred food sources are unavailable (Russell 2020).

Previous studies have demonstrated that forests are often unable to regenerate naturally in areas of high deer density due to severe browsing of young tree seedlings (Matonis et al. 2011). Food resources can decline over time as regeneration is browsed by white-tailed deer, limiting new growth. Previous studies with an overabundance of deer demonstrate damaged forest ecosystems due to browsing (Horvath et al. 2011). Regeneration is very limited or non-existent due to deer browsing on seedlings before they are replaced in the ecosystem. High deer density areas will experience more browsing on understory growth as seedlings serve as accessible food resources (Gill 2001).

Given the negative effects of deer browsing on regeneration, numerous studies have explored various approaches that could be used to mitigate browsing damage on tree seedlings. For example, a study based on Stewart Island, New Zealand compared seedling growth with deer enclosures and without (Stewart & Burrows 1989). In the absence of white-tailed deer in the study, hardwood trees and shrubs preferred by deer were more abundant. Treatment areas that were conducted in browse areas had fewer saplings and limited success in sapling recruitment. Similarly, a study based on Anticosti Island, Quebec, found that browsing by a high-density white-tailed deer population reduced regeneration of preferred tree species (Casabon & Pothier 2008). The project compared unfenced and fenced plots to protect select vegetation which resulted in a significant reduction in overall vegetation cover of preferred species in unfenced areas.

Physical barriers are an effective way to exclude deer from reaching new growth. Control factors such as fencing can be used to deter deer from entering tree plots (Stange 2008). Other methods of exclusion may include individual plant barriers, repellents, population control, use of interceptor food plots, and planting of deer-resistant tree species. Deer-resistant trees are known as species that deter deer from browsing or an undesirable species (BGN 2023). Qualities of trees that decrease deer interactions can include unappealing foliage texture, bitter taste, strong scents, and thorns. The ability to resist deer browsing is dependent on a variety of factors such as the local environment, population, and quantity of alternative food sources (Stange 2008).

The objective of this thesis was to compare the effects of white-tailed deer (*Odocoileus virginianus*) browsing on the height growth of tree seedlings that are controlled using fences compared to non-controlled areas. I predicted that 1) seedlings in nonfenced plots will be more browsed, leading to reduced height growth compared to seedlings within exclusion fencing, and 2) deciduous species will experience more browsing than coniferous species, and 3) seedlings in bush areas will be more intensively browsed than seedlings in open areas.

LITERATURE REVIEW

Ecology of White-tailed Deer

The range of white-tailed deer is exceptionally large in Ontario, including all parts of the province except for the very northernmost regions. Ecosystem conditions vary across the range, from agricultural regions of southern Ontario to the boreal forest of northern Ontario (OMNR 2024a). The estimated number of white-tailed deer in Ontario is approximately 400 000 (Harris 2019), with the highest densities occurring in the southernmost areas, including Cervid Ecological Zones E1, E2, and E3 (Figure 1) (OMNR 2024a). White-tailed deer typically inhabit open woodlands, forested areas, farmland, and suburban regions. Cover is essential for deer survival as it provides protection from predators and allows access to food in its local environment (Voigt et al. 1997). However, the habitat must contain adequate food resources, such as herbaceous plants and trees, to support energy consumption.

Year-round browsing is conducted by white-tailed deer, which is a main source of nutrients in their diet (Jackson & Finley 2021). Herbaceous plant availability is associated with increased feeding opportunities, and deciduous tree species are preferred because they allow for higher energy consumption. Seasonal differences in diet may include the switch to coniferous foliage browse throughout the winter when hardwood browse is less available (Crawford 1982). In the southern forest region, common browse species are *Acer*, *Pinus*, *Quercus*, *Thuja*, *Betula*, and *Tsuga* (Russell 2020). Other associates in southern Ontario forests that would be considered for browse include *Fagus*, *Ostrya*, *Tilia*, *Prunus*, *Populus*, and *Juglans* (Elliot 1998).

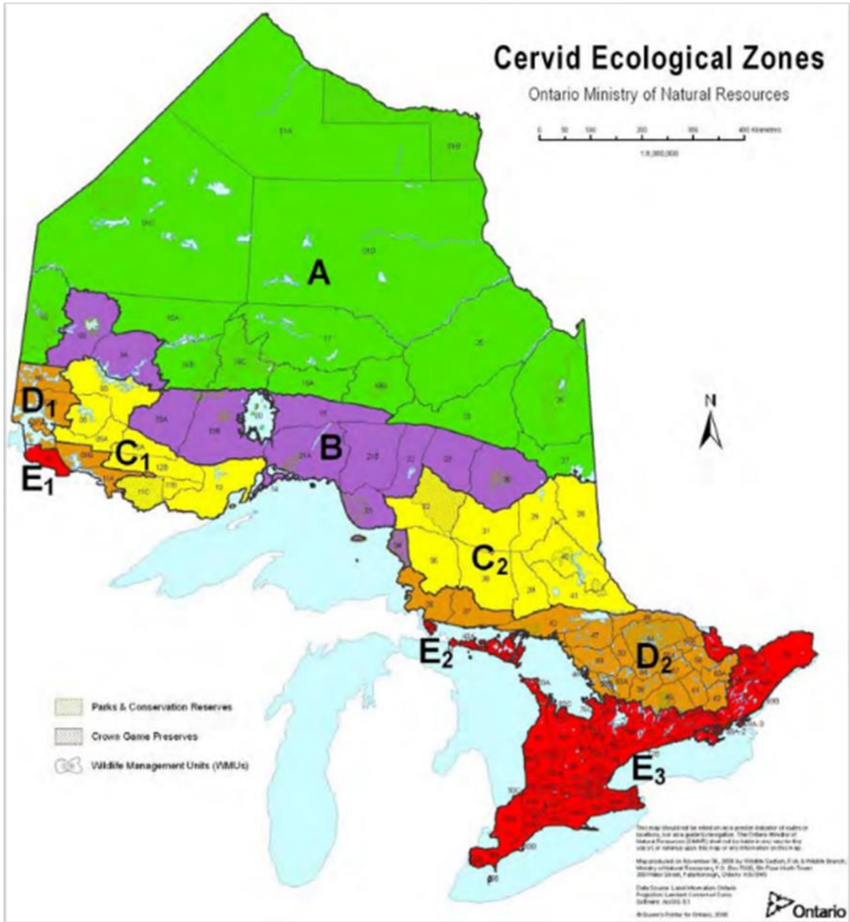

Figure 1. Cervid Ecological Zones. Source: OMNR (2024a)

White-tailed Deer Effects on Forest Regeneration

White-tailed deer populations pose a threat to the regeneration of northern hemisphere forests (Boroski et al. 2021), as a high deer population can potentially consume more food than the amount that can grow each year (Voigt et al. 1997). Intense browsing in areas of high deer density can lead to a phenomenon known as ‘over browsing', in which the growth and survival of young seedlings are severely reduced (Kushneryk 2022). Evidence of an over-browsed region can be determined from missing young trees and buds from vegetation in reach of deer. The vulnerability of trees to browsing is greatest at seedling and sapling stages and declines with time as the terminal leader of a tree becomes out of reach from deer (Patton et al. 2018).

Currently, in the northern hemisphere deer populations have been increasing (Boroski et al. 2021). A consequence of this increase is greater browsing pressure on saplings and limited regeneration in some areas. Research has shown the highest intensity of browsing in saplings occurred in areas with the highest deer density (Borowski et al. 2021). When large populations of deer occur in an isolated area such as an island, expansion of their range for foraging cannot be achieved. Therefore, deer will continue browsing available understory growth species as their food resource, leading to a lack of tree seedlings and understory growth (Côté et al. 2004).

Island populations of white-tailed deer are prone to high deer densities, which currently occur in the study area (WMU 83B). The large population impacts plant species, altering species composition, and reducing tree regeneration due to intensive browsing (Arcese & Martin 2020; Tesoriero et al. 2007). The geographic location and absence of predators contribute to this high deer population (McShea 2012). As deer reach carrying capacity, plant communities struggle with browsing pressure, necessitating human intervention like hunting regulations or predator reintroduction.

Browse Management

Due to the negative effect of deer browsing, considerable amounts of funding have been dedicated to reducing deer impacts on forestry and agricultural crop species (Borowski et al. 2021). Control factors can be used to reduce deer browsing such as cages and fences (Crouch 1976). Methods of excluding deer are in place to reduce deer damage to a specific area but require maintenance and correct installation. Areas experiencing high deer browse may benefit from deer exclusion. The most effective way to prevent deer from browsing is a physical exclusion barrier (MDNR 2023). Nonelectric or electric fencing can be placed around the perimeter of the plants or trees to exclude deer from entering. Mesh netting is another technique used to exclude deer from entering a controlled area. Lastly, an individual plant caging can enclose a species to eliminate browsing. The most effective prevention from deer browsing is fencing which is the most reliable and cost-effective strategy that only requires some maintenance (MDNR 2023). Effective deer exclusion fences facilitate regeneration, protecting seedlings from browsing (WRC 2024). Seedlings should be protected until they surpass typical deer browse heights of two to three meters (Russell 2020).

Tolerance is a characteristic found in some trees, defined as the ability of trees to maintain growth even when under stress (Zeide 1985). Using tolerant or resistant species can allow for regeneration success and higher survival rates. Table 1 outlines the species characteristics relevant to white-tailed deer browsing on trees used in the study including eastern white pine and autumn blaze maple.

Table 1. Species Characteristics

Species	Characteristics
Family: *Aceraceae* Genus: *Acer* Species: *A.freemanii*	• Function as a primary food source for white-tailed deer • Deer resistant and can continue growth depending on browse severity (Barnes 2023) • A nutritious food source that is easily digestible for white-tailed deer (Crawford 1982) • Impact on new growth is more significant
Family: *Pinaceae* Genus: *Pinus* Species: *P. strobus*	• Highly palatable • Reduced long-term success in regeneration from substantial amounts of browsing (Patton et al. 2021). • Secondary food source for white-tailed deer • Fourteen percent of white-tailed deer diet (Fisher & Klocksien 2003).

WMU 83B Ecology

Wildlife management units (WMUs) are used in Ontario as part of a system for the sustainable management of game animals. Ontario is divided into ninety-five WMUs across the province (OMNR 2024b). WMU 83B is the largest island of three situated in Georgian Bay, North of Colpoys Bay, and Owen Sound. It is approximately three miles from the Big Bay dock on the mainland. Plant and animal communities heavily rely on their island ecosystem for survival as it is isolated. Forested parts of the island cover 74%, equivalent to 1,420 acres of land, and contain numerous tree species but are dominated by *Thuja occidentalis, Tilia americana,* and *Fagus grandifolia* (EFSI 2020). Species such as *Quercus, Populus, Fraxinus, Betula, Acer,* and *Ostrya* are also common along with some coniferous trees. The majority of the soil on the island is comprised of shallow to moderately deep, stony, moderately drained clay loam soils (EFSI 2020). The most common wildlife species in this WMU are the white-tailed deer and eastern wild turkey (*Meleagris gallopavo*). The white-tailed deer is the most significant in terms of ecological impact, as there is currently a high deer density in the WMU. Additionally, there is no pressure on the deer from predator species. The population of deer makes the regeneration of native trees exceedingly difficult without human innovation due to the high browsing intensity. WMU 83B has existing cropland and regeneration of select species for deer feeding but limited new growth of woody browse material has contributed to an ecological problem from long-term over-browsing (EFSI 2020).

The 2023 white-tailed deer population census in WMU 83B was approximately 233 total deer and was calculated post-spring recruitment (Woodhall, S., personal communication, March 26, 2024). Population density is estimated to be 14 deer per acre in the region. However, based on harvest management in 2023, the population dropped to 160 deer for the winter months. Mortality over winter months is historically up to 15% of the total population.

Forest management in WMU 83B has historically been conducted for the improvement of the forested regions on the island. Approximately 30,000 coniferous trees including eastern white cedar, eastern white pine, and red pine, were machine planted in field areas in 1981 but failed due to poor site conditions and deer browsing (EFSI 2020). In the year 2000, a total of 6,500 coniferous trees were planted in multiple locations throughout the island, which included eastern white pine, white spruce, and Norway spruce species (EFSI 2020). This was conducted in regions of fields to enhance wildlife coverage with spruce having the highest survival rate among seedlings. Between the years of 2001 and 2010, there were several plantations in woodland areas of the island estimated at 8,000 spruce and 220 mixed deciduous trees (EFSI 2020). A total of 30,400 bare-root tree seedlings were planted between the years 2013 and 2014 including white spruce, Norway spruce, eastern white pine, and tamarack (ESFI 2020). By 2018, several of these species were replanted due to low survival rates in all seedlings. Based on recent observations, there was no evident tamarack or eastern white pine survival and all trees in the latest plantation had less than 60% survival rates (EFSI 2020). A combination of factors significantly impacted the seedling survival including high vegetative competition, poor site conditions from soil and drought, and some white-tailed deer browsing.

Commercial timber harvesting has not historically taken place in WMU 83B, although selective harvesting of eastern white cedar has taken place for small-scale usage (EFSI 2020). There was a focus on leaving residual trees in the region to support regeneration. The majority of the island has a parkland appearance with distinct browse lines in several mature trees such as eastern white cedar. WMU 83B has contained high densities of deer for approximately 60 years, making regeneration very limited for both hardwood and coniferous tree species. Supplementary winter feeding has been conducted to support the white-tailed deer population and reduce annual mortality. In recent years, there has been the establishment of 32 acres of deer food plots to supplement feeding. Lastly, an increase in hunting pressure has been permitted by the Ministry of Natural Resources in WMU 83B to help reduce deer density.

METHODS

Study Area

The study area is based on an island located on Lake Huron in Georgian Bay, North of Owen Sound, Ontario (Figure 2). The island is part of the wildlife management unit (WMU) 83B, which falls within the Great Lakes-St. Lawrence Forest region. The island has a combination of forested land, agricultural crops, grasslands, rocky shorelines, and unoccupied areas. The total area of the island is equivalent to 1,938 acres with 1,420 acres of forested land. Forested land is occupied mostly by native deciduous species (79%) and some coniferous species (21%). Regeneration of shrubs and trees is exceptionally low in this region from high-intensity browsing by white-tailed deer. Stony, loamy clay soil and mild temperatures are a characteristic of this area.

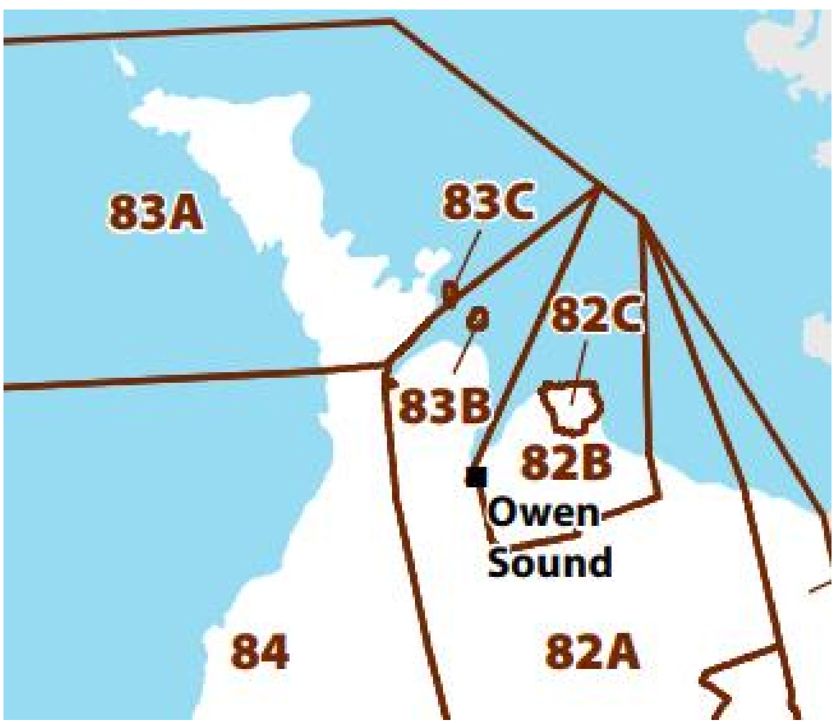

Figure 2. Location of the island study area in WMU 83B. Source: OMNR (2024b)

Sample Design

Two plantation areas were established, one plantation is in an open field area, and one is in a forested area with partial shade. Each plantation has one exclusion (fenced) plot and one control (non-fenced) plot with a total of four plots created on the northeast side of the island. Exclusion plots were double-fenced and constructed using 2-meter metal posts on each corner pushed into the soil with electric fencing wire weaved through the posts. Gallagher branded wiring (64 m) was used, powered with Gallagher solar paneled charging boxes. The exclusion and control plots in the same plantation were spaced approximately 2 meters apart.

The open and bush plantation areas contained similar tree species composition, although there were some differences in shrub and herbaceous vegetation cover. The open plantation had nearby mature trees and shrubs including *Tilia*, *Quercus*, *Ulmus*, *Prunus*, and *Alnus*. The bush plantation had similar mature species including *Picea*, *Tilia*, *Quercus*, and *Alnus*. In both areas, there was evidence of deer damage on surrounding trees and shrubs. The soil was evaluated in the open field area and the forested area to obtain the differences between the locations. Soil testing was conducted using a HoldAll branded test to demonstrate pH levels and a range of low to high amounts of nitrogen (N), phosphorous (P), and potassium (K) in each plantation. These nutrients were low in both sites. The pH level in the open plantation was 7.0 and 6.0 in the bush plantation.

The plots in the forested area were located at approximately 44.8376137, -80.8939731 coordinates. The fenced plot dimensions are 3.7 m by 4.9 m on the outside and another fenced plot is 30 cm inside with dimensions 3.4 m by 4.6 m. The non-fenced plot dimensions are 1.5 m by 3.05 m. The open field area plots were located at 44.8344851, -80.8948817 coordinates. The fenced plot dimensions are 3.2 m by 4.8 m on the outside and 2.9 m by 4.5 m on the inside. The non-fenced plot dimensions are 1.6 m by 2.8 m.

The seedlings used for the experiment were eight *Acer freemanii* purchased from Martin's Family Tree Farm and Bee Supplies in Wroxeter, Ontario. Sixteen *Pinus strobus* were supplied by a not-for-profit organization which were purchased from Somerville Seedlings in Everett, Ontario, and shipped to WMU 83B. Tree species were used to test the intensity of browsing and survival of deciduous and coniferous tree seedlings. Two *Acer freemanii* and four *Pinus strobus* trees were planted in each of the four plots using a spade shovel and watered as needed.

Data Collection and Statistical Analysis

All study trees were measured each week during the study period from May to August 2023. Measurements were taken from the base of the stem to the terminal bud to observe height over time using a Crescent Lufkin 25' measuring tape. Browse intensity was observed by measuring the browse percentage on each tree weekly. Analysis of the data was conducted using Microsoft Excel. I calculated mean height and browse percentage for each treatment combination, and these were graphed to illustrate height over the twelve-week study period. Browsing percentages were calculated based on the number of species browsed divided by total species type in a plot.

RESULTS

Fenced Versus Unfenced

Fenced plots exhibit no disruption from browsing by white-tailed deer. Seedlings that were protected by fencing had no disruption to height growth over time in comparison to trees without fencing, enhancing their survival. All plots that had fencing enclosures demonstrated slow growth throughout the study period (Figures 3a and 3b). Although, there were no disruptions from browsing, slow growth rates were observed for seedlings even in the fenced plots.

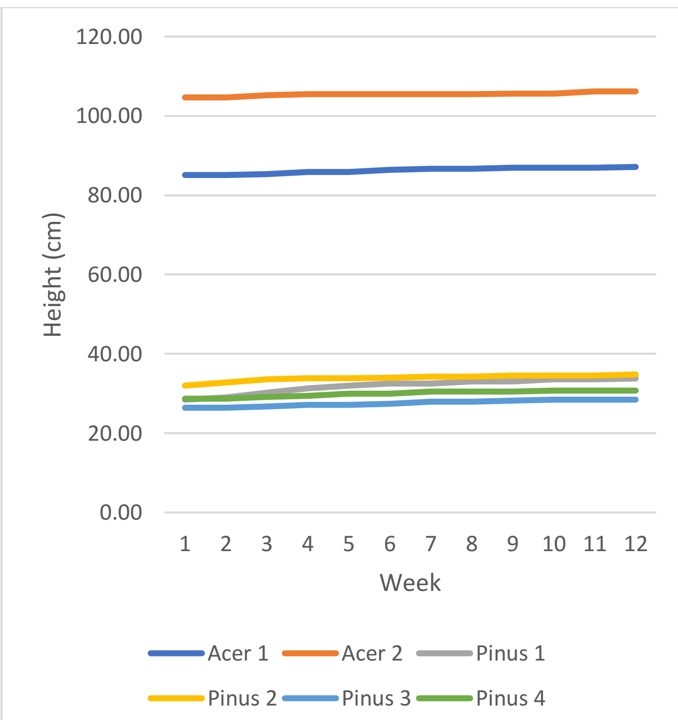

Figure 3a. Species Height in Fenced Open Area

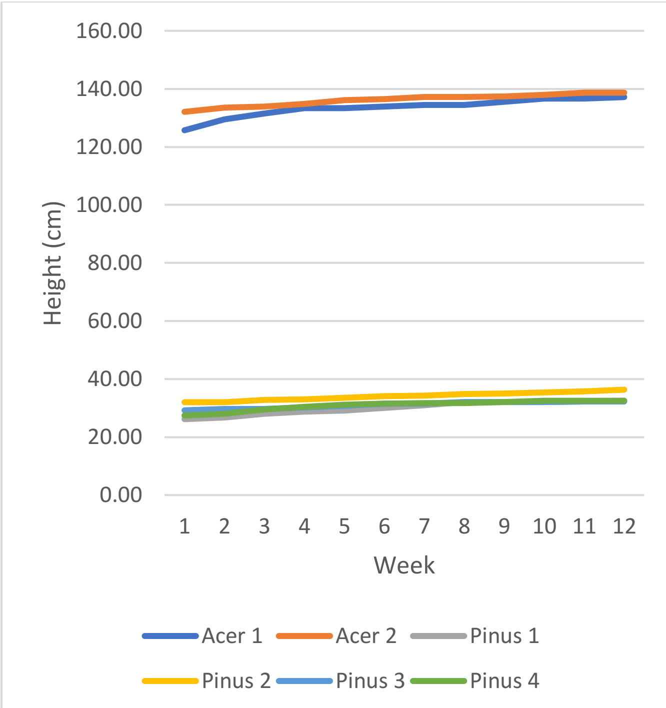

Figure 3b. Species Height in Fenced Bush Area

Unfenced seedlings had some disruptions to growth due to browsing by white-tailed deer. All maple species that were not surrounded by fencing experienced damage by white-tailed deer and some pines as well. As a result, the height decreased for trees in unfenced plots (Figures 4a and 4b). For example, maple 2 in the unfenced bush plantation decreased from 119.38 cm in height in week two to 115.57 cm in week three (Figure 4b). All maple trees in unfenced plots experienced browsing but showed resilience by continuing growth later in the study period. For example, the maples in the open plantation were browsed by week three but continued growth in weeks seven and nine (Figure 4a). Pine trees in both plantations that were browsed did not resume growth after the disruption. An example of this is pine 4 in the unfenced open plantation that was browsed in week 7 with no evidence of growth after disruption through the duration of the study (Figure 4a).

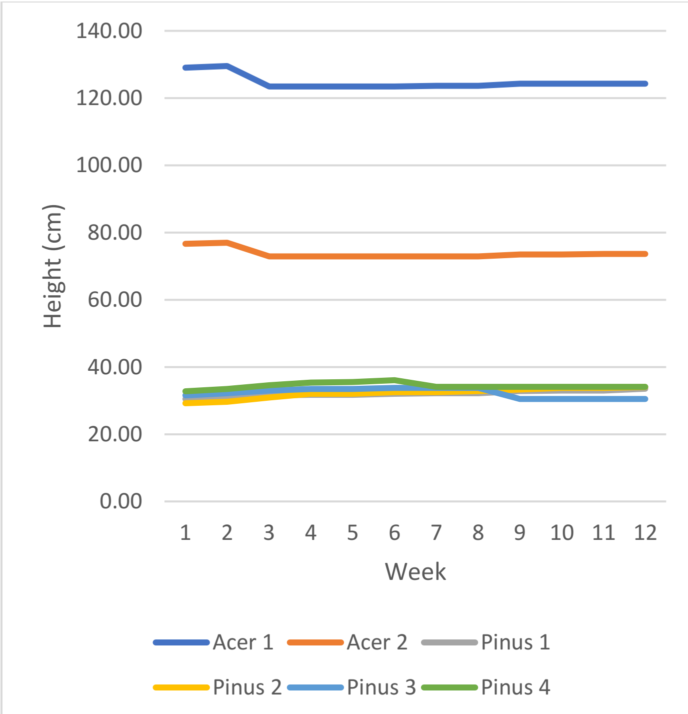

Figure 4a. Species Height in Unfenced Open Area

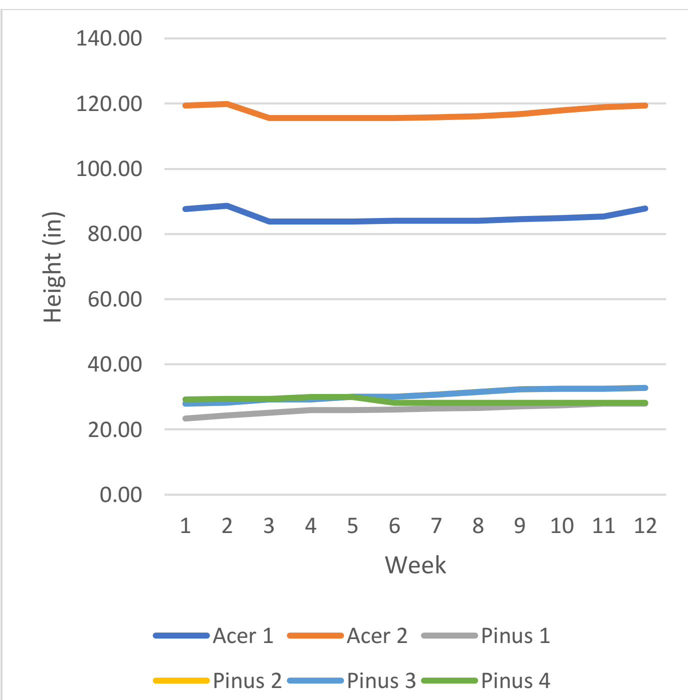

Figure 4b. Species Height in Unfenced Bush Area

Maple Versus Pine

Maples in the study period were browsed quicker and more intensively than pines. All maples in plots without electrical fencing were browsed by white-tailed deer (Figure 5). The open plantation plot without fencing (plot B), had 50% browse on pines, while the bush plantation without fencing (Plot D) was 25% browsed. Maple browsing occurred earlier in the study period in week three. Browsing on pines occurred later in the study period by weeks seven and nine. Overall, more browsing occurred in the open plantation and the majority of trees browsed were maple seedlings.

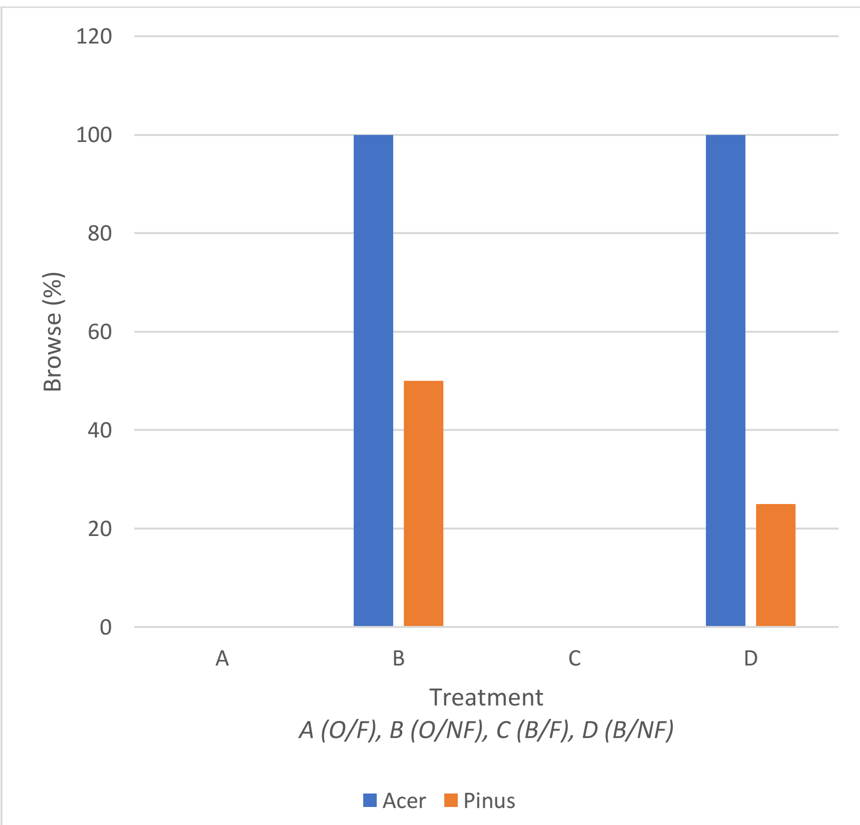

Figure 3. Average Species Browse (%)

Open Versus Bush Sites

The bush area plantation supported an overall greater height in tree species (Figure 8). Maples and pines had the highest height growth in the fenced bush plantation (plot C). For example, the average maple height was 137.92 cm and the average pine height was 33.3 cm in plot C. Secondly, maples in the unfenced bush plantation (plot D) had the next highest height averages compared to maples in the open plantations. The open plantation supported the lowest height averages in maples for both plots A and B and pines for plot A.

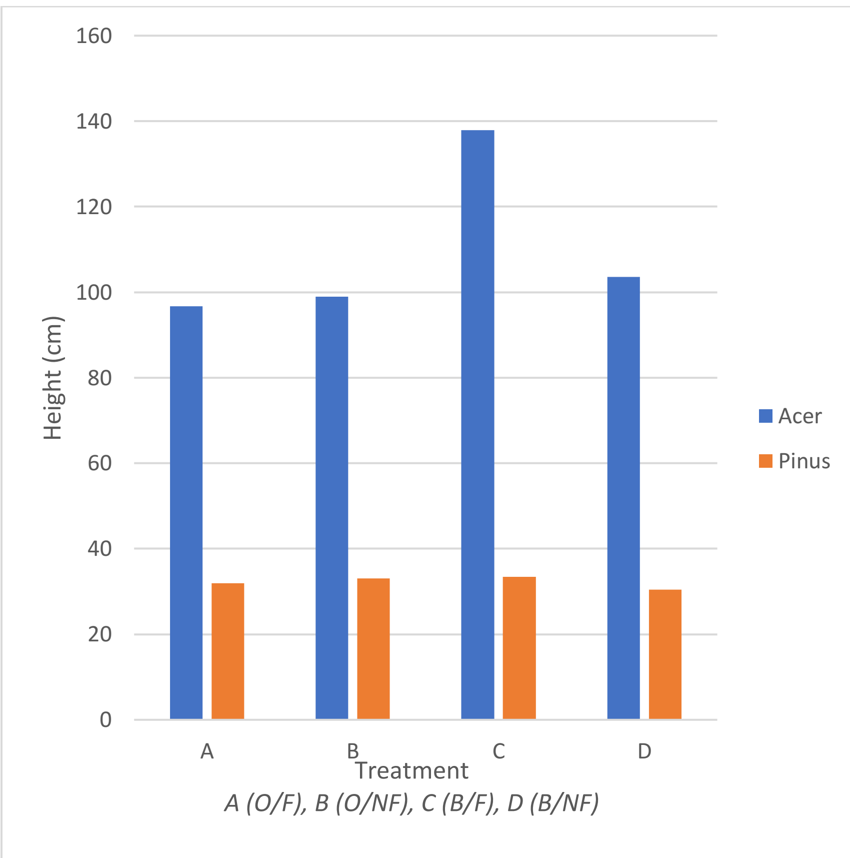

Figure 6. Average Species Height Growth

DISCUSSION

Deer Exclusion Areas

The results of this study support my first prediction that seedlings in nonfenced areas will experience greater browsing. Seedlings in the unfenced area experienced much higher browsing and had reduced height growth compared to seedlings in fenced enclosures. However, height growth over the study period was slow even in the fenced plots. This slow growth that I observed could be an indicator of plantation shock, defined as the tree failing to root well because of poor establishment in a new environment (Pecknold 2021). Stress can evolve due to transplanting trees from a nursery to a forested site (Burdett 1990), especially when seedlings are planted in hot, dry periods. Tree seedlings are best planted in the early spring or late autumn to maximize establishment success and subsequent growth (NYBG 2022). However, the seedlings in my study were planted in late May and early June when soils were dry and daily temperatures averaged around 18°C (Climate Data 2024).

Differences Among Tree Species

Throughout the study, greater browsing occurred on *Acer freemanii* seedlings in all plots without a fence. *Pinus strobus* had less browsing in the plots without a fence, with more in the open plantation. This species is difficult to restore as white-tailed deer will browse these species before most other coniferous trees (Fisher & Klocksien 2003). Due to seasonal preferences, *Acer* trees were browsed first because they are highly palatable and digestible (Crawford 1982). Often hardwoods are selected for browsing in the late spring and summer months while foliage and buds are present. Conifers are a secondary food choice, meaning they are often browsed in the winter months by white-tailed deer (Crawford 1982). The white-tailed deer in WMU 83B were browsing on *Pinus strobus* regardless of the season, suggesting that high deer densities have reduced the availability of preferred food sources (Hanberry & Abrams 2019).

The majority of *Pinus strobus* seedlings had greater growth compared to *Acer freemanii* in all plantations without a fence during the study period. Both *Pinus strobus* and *Acer freemanii* species are fast-growing trees on high-quality planting sites. However, suppressed *Pinus strobus* seedlings will grow less than 2.5 centimeters but can grow much more in better conditions during a growing season (Martin & Lorimer 1997). Under optimal growing conditions, *Acer freemanii* can grow very quickly at about 60 centimeters per year (ADF 2024). Thus, I believe that the higher growth of the *Pinus* seedlings in my study was due to less disruption to growth from less browsing in the *Pinus* seedlings in comparison to *Acer*.

Acer species can increase growth quickly following a disturbance (Jevon 2013). In this study, I observed that *Acer freemanii* species were able to continue height growth following browsing, making them somewhat deer-resistant. Disturbance such as herbivory of *Pinus strobus* soon after planting can initially reduce seedling height by removal of shoots (South et al. 2023). Although seedling growth can recover over time (given that seedlings are not suppressed by other plants) (South et al. 2023). I observed that *Pinus strobus* seedlings in my study did not continue height growth immediately following browsing.

Open Sites Versus Bush Sites

Browsing from white-tailed deer occurred within plots in both plantation types, although higher indicators of browse occurred in the open plantation. The greater deer damage in the open plantation could be due to higher availability of low trees and shrubs. As low shrubs and trees are targeted for browse by white-tailed deer (Voigt et al. 1997), this may serve to deer as areas for feeding.

Plots in the bush area had greater height growth than the open plantation for both *Pinus strobus* and *Acer freemanii.* Differences in plantation conditions include sunlight distribution full in the open but partial shading in the bush plantation. There is a higher potential for growth to occur in the bush plantation with competition from understory plants. Canopy coverage in the bush-covered area was higher, and so increased tree growth in the bush plots might be due to higher soil moisture availability (Maloney 2007). In addition, partial shading reduces solar heat and lowers daytime temperatures (Lin & Lin 2010), reducing evapotranspiration and water stress. The lower pH in the bush area plantation compared to the open plantation could be associated with reduced nutrient leaching and greater availability of exchangeable cations like calcium and magnesium.

CONCLUSION

This study confirms several predictions concerning the impact of white-tailed deer browsing on tree seedlings in WMU 83B. Firstly, seedlings in unfenced areas were significantly more susceptible to browsing, resulting in reduced height growth compared to plots within exclusion fencing. This demonstrates the importance of using protective measures such as fencing to reduce browsing pressure and promote seedling growth. Secondly, the study showed that *Acer freemanii* seedlings were more heavily browsed than *Pinus strobus*, aligning with the seasonal and dietary preferences of white-tailed deer. Despite being preferred for browsing, *Acer freemanii* demonstrated resilience by continuing growth after browsing disturbance, emphasizing its suitability as a fast-growing, tolerant species for regeneration in WMU 83B. Thirdly, seedlings in bush plantations experienced more intensive browsing compared to those in open areas, likely due to the higher availability of low trees and shrubs which are preferred by white-tailed deer. However, bush plantations provided more favorable growing conditions, resulting in higher height growth compared to open plantations for both *Acer* and *Pinus* seedlings. Overall, the study demonstrates the need for effective management and conservation strategies to protect regenerating seedlings from the adverse effects of high deer densities in WMU 83B. Implementing more conservation efforts, such as deer exclusion fencing and selective planting of resilient tree species, will be essential for enhancing forest regeneration, promoting biodiversity, and ensuring long-term sustainability with continued browsing pressure from white-tailed deer.

LITERATURE CITED

Akashi, N., Unno, A., & Uno, H. (2022). The browsing ratio as an index of the impact of deer browsing on tree seedlings. *Trees, Forests and People*, *8*, 100276. https://doi.org/10.1016/j.tfp.2022.100276

Arbor Day Foundation (ADF). (2024). *Autumn Blaze maple*. Arbor Day Foundation. https://shop.arborday.org/autumn-blaze-maple-2#:~:text=Look%20no%20further%20than%20the,averaging%20two%20feet%20per%20year

Arcese, P. and Martin, T. (2020). *Deer and Biodiversity*. University of British Columbia. https://ibis.geog.ubc.ca/biodiversity/InfluencesonBiodiversity--Deer.html

Barnes, S. (2023). *Are maple trees deer resistant?* Plant Addicts. https://plantaddicts.com/are-maple-trees-deer-resistant/

Blue Grass Nursery (BGN). (2023). *Deer resistant trees*. Blue Grass Nursery, Sod and Garden Centre: Calgary, Edmonton and Red Deer, Alberta. https://bluegrassnursery.com/deer-resistant-trees/?nocache=

Borowski, Z., Gil, W., Bartoń, K. A., Zajączkowski, G., Łukaszewicz, J., Tittenbrun, A., & Radliński, B. (2021). Density-related effect of red deer browsing on palatable and unpalatable tree species and forest regeneration dynamics. *Forest Ecology and Management*, *496*, 119442. https://doi.org/10.1016/j.foreco.2021.119442

Burdett, A. N. (1990). Physiological processes in plantation establishment and the development of specifications for forest planting stock. *Canadian Journal of Forest Research*, *20*(4), 415–427. https://doi.org/10.1139/x90-059

Casabon, C., & Pothier, D. (2008). Impact of deer browsing on plant communities in cutover sites on Anticosti Island. *ÉCoscience/Écoscience*, *15*(3), 389–397. https://doi.org/10.2980/15-3-3123

Climate Data. (2024). *Owen Sound climate: Weather Owen Sound & temperature by month*. Climate Data. https://en.climate-data.org/north-america/canada/ontario/owen-sound-14243/

Côté, S. D., Rooney, T. P., Tremblay, J., Dussault, C., & Waller, D. M. (2004). Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution, and Systematics*, *35*(1), 113–147. https://doi.org/10.1146/annurev.ecolsys.35.021103.105725

Crawford, H. S. (1982). Seasonal food selection and digestibility by Tame White-Tailed Deer in Central Maine. *The Journal of Wildlife Management*, *46*(4), 974. https://doi.org/10.2307/3808230

Crouch, G.L. (1976). Deer and Reforestation in the Public Northwest. University of Nebraska – Lincoln. USDA Forest Service, *Proceedings of the 7th Vertebrate Pest Conference, 16*, 298-301. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1015&context=vpc7

Ecological and Forestry Services Inc. (2020). *Managed Forest Plan (WMU 83B)*. Ecological and Forestry Services Incorporated (EFSI), 1-32.

Elliott, K. A. (1998). The forests of southern Ontario. *The Forestry Chronicle/Forestry Chronicle*, *74*(6), 850–854. https://doi.org/10.5558/tfc74850-6

Fisher, K. A., & Klocksien, S. (2003). White-tailed deer (Odocoileus virginianus) and the restoration of eastern white pine (Pinus strobus). *Restoration and Reclamation Review*, *8*(4), 1–13. https://conservancy.umn.edu/handle/11299/60238

Gill, R. (2001). The impact of deer on woodlands: the effects of browsing and seed dispersal on vegetation structure and composition. *Forestry*, *74*(3), 209–218. https://doi.org/10.1093/forestry/74.3.209

Hanberry, B. B., & Abrams, M. D. (2019). Does white-tailed deer density affect tree stocking in forests of the Eastern United States? *Ecological Processes*, *8*(1). https://doi.org/10.1186/s13717-019-0185-5

Harris, B. (2019). *2019 Canadian hunting hot spots for deer, moose, elk and more. Outdoor Canada pages 6 - 13*. Outdoor Canada. https://www.outdoorcanada.ca/2019huntinghotspots/6/#:~:text=There%20are%20an%20estimated%20400%2C000,numbers%20there%20will%20be%20down

Horvath, D., Parisio, M., Leopold A., Committee for the University Environment, Curtis and Sullivan, Levine, Cote, Rawinski, Horsley, Rooney and Waller, Tripler et al., & Powers. (2011). *Deer Management Plan –Binghamton University* [Report]. https://www.binghamton.edu/nature-preserve/docs/deer-management-rationale.pdf

Jackson, D.R. and Finley, J. (2021). *Regenerating hardwood forests: Managing competing plants, deer, and light*. PennState Extension. https://extension.psu.edu/regenerating-hardwood-forests-managing-competing-plants-deer-and-light#:~:text=If%20you%20control%20competing%20vegetation,establishing%20and%20sustaining%20new%20forests.

Jevon, F. V. (2013). The Importance of Age, Competition and Succession in Acer rubrum Decline in a Northeastern Mixed Deciduous Forest. In Harvard University, *Harvard University*.https://harvardforest1.fas.harvard.edu/publications/pdfs/Jevon_Thesis_2013.pdf

Kushneryk, K. (2022). *Identifying signs of deer overbrowsing*. Mayne Island Conservancy. https://mayneconservancy.ca/identifying-signs-of-deer-overbrowsing/

Lin, B., & Lin, Y. (2010). Cooling Effect of Shade Trees with Different Characteristics in a Subtropical Urban Park. *HortScience*, *45*(1), 83–86. https://doi.org/10.21273/hortsci.45.1.83

Maloney, L. (2007). *The Effect of Canopy Cover and Soil Conditions on Growth Rate of Mimulus aurantiacus and Rhamnus californica in San Francisco*. https://nature.berkeley.edu/classes/es196/projects/2007final/Maloney.pdf

Martin, J., Lorimer, C. (1997). *How to manage white pine*. University of Wisconsin, United States Department of Agriculture, & Wisconsin counties cooperating. https://forestandwildlifeecology.wisc.edu/wp-content/uploads/sites/111/2017/07/86.pdf

Matonis, M. S., Walters, M. B., & Millington, J. (2011). Gap-, stand-, and landscape-scale factors contribute to poor sugar maple regeneration after timber harvest. *Forest Ecology and Management*, *262*(2), 286–298. https://doi.org/10.1016/j.foreco.2011.03.034

McShea, W. J. (2012). Ecology and management of white-tailed deer in a changing world. *Annals of the New York Academy of Sciences*, *1249*(1), 45–56. https://doi.org/10.1111/j.1749-6632.2011.06376.x

MDNR. (2023). *Deer damage Management Techniques - exclusion methods*. Maryland Department of Natural Resources. https://dnr.maryland.gov/wildlife/pages/hunt_trap/ddmtexclude.aspx

New York Botanical Garden (NYBG). (2022). *Research guides: Conifers: Planting and Maintenance: Home*. New York Botanical Garden. https://libguides.nybg.org/plantmaintainconifer

OMNR. (2024). *White-tailed deer in Ontario*. Ontario Ministry of Natural Resources. ontario.ca. https://www.ontario.ca/page/white-tailed-deer-ontario

OMNR. (2024a). *Cervid ecological framework*. Ontario Ministry of Natural Resources. ontario.ca. https://www.ontario.ca/page/cervid-ecological-framework

OMNR. (2024b). *Find a wildlife management unit (WMU) map*. Ontario Ministry of Natural Resources. ontario.ca. https://www.ontario.ca/page/find-wildlife-management-unit-wmu-map

Patton, S. R., Russell, M. B., Windmuller-Campione, M. A., & Frelich, L. E. (2021). White-tailed deer herbivory impacts on tree seedling and sapling abundance in the Lake States Region of the USA. *Annals of Forest Science*, *78*(4). https://doi.org/10.1007/s13595-021-01108-6

Patton, S. R., Russell, M. B., Windmuller-Campione, M. A., & Frelich, L. E. (2018). Quantifying impacts of white-tailed deer (Odocoileus virginianus Zimmerman) browse using forest inventory and socio-environmental datasets. *PloS One*, *13*(8), e0201334. https://doi.org/10.1371/journal.pone.0201334

Pecknold, P.C. (2021). *BP-31, Ornamental diseases - Transport Shock of Trees and Shrubs*. Department of Botany, Plant, and Pathology, Purdue University. https://www.extension.purdue.edu/extmedia/bp/bp-31.html

Russell, M. (2020). *How to identify deer browse in the woods*. UMN Extension. https://extension.umn.edu/my-minnesota-woods/how-identify-deer-browse-woods

South, D. B., Starkey, T. E., & Lyons, A. (2023). Why Healthy Pine Seedlings Die after They Leave the Nursery. *Forests*, *14*(3), 645. https://doi.org/10.3390/f14030645

Stange, C. (2008). *Protecting trees and shrubs from deer*. USDA Natural Resources Conservation Service - North Dakota, Southern Forest Insect Work Conference, North Dakota Game and Fish, USDA, & NRCS. https://www.nrcs.usda.gov/sites/default/files/202212/nrcs141p2_001562_Protecting%20Trees%20and%20Shrubs%20From%20Deer.pdf

Stewart, G. H., & Burrows, L. (1989). The impact of white-tailed deer Odocoileus virginianus on regeneration in the coastal forests of Stewart Island, New Zealand. *Biological Conservation*, *49*(4), 275–293. https://doi.org/10.1016/0006-3207(89)90048-7

Tesoriero, K., Tiebout, H. M., & Hertel, G. (2007). The Effects of Deer and Non-native Invasive Plants on Native Plants: Demonstration Area in the Gordon Natural Area on the Campus of West Chester University of Pennsylvania, West Chester, Chester County: base-line plant data. *West Chester University Digital Commons, West Chester University*, 1–34. https://digitalcommons.wcupa.edu/cgi/viewcontent.cgi?article=1002&context=gna_dnipi_series

Voigt, D. R. (1997). *Forest Management Guidelines for the Provision of White-tailed Deer Habitat*. https://dr6j45jk9xcmk.cloudfront.net/documents/2811/guide-whitetail-deer.pdf

Wildlife Resources Commission (WRC). (2024). *Whitetail Deer – Fencing to Exclude Deer. North Carolina Wildlife Resources Commission*. Wildlife Resources Commission. https://www.ncwildlife.org/Learning/Species/Mammals/Whitetail-Deer/Fencing-toExcludeDeer#:~:text=Vertical%20fences%20are%20effective%20at,physically%20impeded%20by%20the%20barrier

Zeide, B. (1985). Tolerance and self-tolerance of trees. *Forest Ecology and Management*, *13*(3–4), 149–166. https://doi.org/10.1016/0378-1127(85)90031-3

APPENDIX

Plot 1. Open Area with a Fence

Species	***Acer***		***Acer***		***Pinus***		***Pinus***		***Pinus***		***Pinus***	
Week	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)
1	85.09	0.00	104.65	0.00	28.45	0.00	32.00	0.00	26.42	0.00	28.70	0.00
2	85.09	0.00	104.65	0.00	28.96	0.00	32.77	0.00	26.42	0.00	28.70	0.00
3	85.34	0.00	105.16	0.00	30.23	0.00	33.53	0.00	26.67	0.00	29.21	0.00
4	85.85	0.00	105.41	0.00	31.24	0.00	33.78	0.00	27.18	0.00	29.46	0.00
5	85.85	0.00	105.41	0.00	32.00	0.00	33.78	0.00	27.18	0.00	29.97	0.00
6	86.36	0.00	105.41	0.00	32.51	0.00	34.04	0.00	27.43	0.00	29.97	0.00
7	86.61	0.00	105.41	0.00	32.51	0.00	34.29	0.00	27.94	0.00	30.48	0.00
8	86.61	0.00	105.41	0.00	33.02	0.00	34.29	0.00	27.94	0.00	30.48	0.00
9	86.87	0.00	105.66	0.00	33.02	0.00	34.54	0.00	28.19	0.00	30.48	0.00
10	86.87	0.00	105.66	0.00	33.53	0.00	34.54	0.00	28.45	0.00	30.73	0.00
11	86.87	0.00	106.17	0.00	33.53	0.00	34.54	0.00	28.45	0.00	30.73	0.00
12	87.12	0.00	106.17	0.00	33.78	0.00	34.80	0.00	28.45	0.00	30.73	0.00

Plot 2. Open Area - No Fence

Species	***Acer***		***Acer***		***Pinus***		***Pinus***		***Pinus***		***Pinus***	
Week	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)
1	129.03	0.00	76.71	0.00	30.48	0.00	29.21	0.00	31.50	0.00	32.77	0.00
2	129.54	0.00	76.96	0.00	30.73	0.00	29.72	0.00	32.26	0.00	33.53	0.00
3	123.44	0.50	72.90	0.50	31.50	0.00	30.99	0.00	33.02	0.00	34.54	0.00
4	123.44	0.50	72.90	0.50	31.75	0.00	32.00	0.00	33.53	0.00	35.31	0.00
5	123.44	0.50	72.90	0.50	31.75	0.00	32.00	0.00	33.53	0.00	35.56	0.00
6	123.44	0.50	72.90	0.50	32.00	0.00	32.51	0.00	33.78	0.00	36.07	0.00
7	123.70	0.50	72.90	0.50	32.26	0.00	32.51	0.00	33.78	0.00	34.04	0.25
8	123.70	0.50	72.90	0.50	32.26	0.00	32.77	0.00	33.78	0.00	34.04	0.25
9	124.21	0.50	73.41	0.50	32.77	0.00	33.27	0.00	30.48	0.25	34.04	0.25
10	124.21	0.50	73.41	0.50	33.02	0.00	33.78	0.00	30.48	0.25	34.04	0.25
11	124.21	0.50	73.66	0.50	33.02	0.00	33.78	0.00	30.48	0.25	34.04	0.25
12	124.21	0.50	73.66	0.50	33.53	0.00	34.04	0.00	30.48	0.25	34.04	0.25

Plot 3. Bush Area - Fence

Species	***Acer***		***Acer***		***Pinus***		***Pinus***		***Pinus***		***Pinus***	
Week	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)
1	125.73	0.00	132.08	0.00	26.16	0.00	32.00	0.00	29.21	0.00	27.43	0.00
2	129.54	0.00	133.60	0.00	26.67	0.00	32.00	0.00	29.72	0.00	27.94	0.00
3	131.57	0.00	133.86	0.00	27.94	0.00	32.77	0.00	29.72	0.00	29.46	0.00
4	133.35	0.00	134.87	0.00	28.70	0.00	33.02	0.00	30.23	0.00	30.48	0.00
5	133.35	0.00	136.14	0.00	29.21	0.00	33.53	0.00	30.73	0.00	31.24	0.00
6	133.86	0.00	136.40	0.00	29.97	0.00	34.04	0.00	31.50	0.00	31.50	0.00
7	134.37	0.00	137.16	0.00	30.99	0.00	34.29	0.00	31.50	0.00	31.75	0.00
8	134.37	0.00	137.16	0.00	32.00	0.00	34.80	0.00	32.00	0.00	31.75	0.00
9	135.64	0.00	137.41	0.00	32.00	0.00	35.05	0.00	32.00	0.00	32.00	0.00
10	136.65	0.00	137.92	0.00	32.00	0.00	35.31	0.00	32.00	0.00	32.51	0.00
11	136.65	0.00	138.68	0.00	32.26	0.00	35.81	0.00	32.26	0.00	32.51	0.00
12	137.16	0.00	138.68	0.00	32.51	0.00	36.32	0.00	32.26	0.00	32.51	0.00

Plot 4. Bush Area - No Fence

Species	***Acer***		***Acer***		***Pinus***		***Pinus***		***Pinus***		***Pinus***	
Week	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)	Height (cm)	Browse (%)
1	87.63	0.00	119.38	0.00	23.37	0.00	27.94	0.00	27.94	0.00	29.21	0.00
2	88.65	0.00	119.89	0.00	24.38	0.00	28.19	0.00	28.19	0.00	29.46	0.00
3	83.82	0.50	115.57	0.50	25.15	0.00	29.21	0.00	29.21	0.00	29.46	0.00
4	83.82	0.50	115.57	0.50	25.91	0.00	29.21	0.00	29.21	0.00	29.97	0.00
5	83.82	0.50	115.57	0.50	25.91	0.00	29.97	0.00	29.97	0.00	29.97	0.00
6	84.07	0.50	115.57	0.50	26.16	0.00	29.97	0.00	29.97	0.00	28.19	0.25
7	84.07	0.50	115.82	0.50	26.42	0.00	30.73	0.00	30.73	0.00	28.19	0.25
8	84.07	0.50	116.08	0.50	26.67	0.00	31.50	0.00	31.50	0.00	28.19	0.25
9	84.58	0.50	116.84	0.50	27.18	0.00	32.26	0.00	32.26	0.00	28.19	0.25
10	84.84	0.50	117.86	0.50	27.43	0.00	32.51	0.00	32.51	0.00	28.19	0.25
11	85.34	0.50	118.87	0.50	27.94	0.00	32.51	0.00	32.51	0.00	28.19	0.25
12	87.88	0.50	119.38	0.50	27.94	0.00	32.77	0.00	32.77	0.00	28.19	0.25