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White-tailed deer *(Odocoileus virginianus)* and the Restoration of Eastern White Pine (*Pinus strobus)*

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Introduction

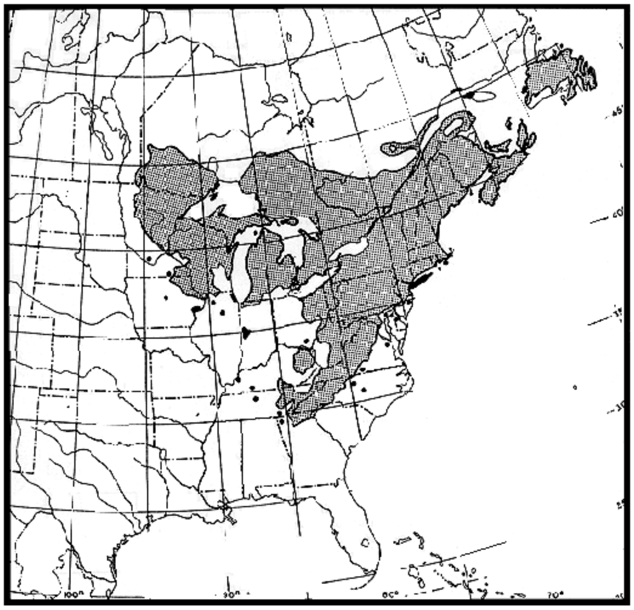
In the past, eastern white pine (*Pinus strobus*) forests were plentiful in the northern regions of the United States, covering vast hectares of land. Pressures from past logging practices in the 1800's and early 1900's, and disease such as white pine blister rust (*Cronartium ribicola)* diminished this range (Vogt personal communication 2003). Currently, white pine forests cover only a fraction of the historical area, existing mostly in isolated patches. During the 1990's interest in restoring stands of eastern white pine increased. Restoration projects began to emerge across the Northeastern United States in response to this interest. These efforts have, however, experienced some difficult challenges. Recent monitoring of current restoration projects has revealed a high mortality rate in young saplings; this is attributed primarily to the increase in white-tailed deer (*Odocoileus virginianus*) populations that browse upon the white pine seedlings. White-tailed deer have the potential to cause severe stress in reforestation projects due to their browsing behavior and densities.

Management objectives differ between maintaining white-tailed deer populations and restoring the eastern white pine, causing uncertainty for selecting optimal strategies. This struggle has been brought to the natural resources forefront by public and governmental agencies in many northern U.S. regions, generating debate on how best to simultaneously restore pine forest and maintain huntable white-tailed deer populations. The following is a discussion of why eastern white pine forest restoration is needed, how increasing white-tailed deer populations can be detrimental to this restoration, and finally which different management techniques can be implemented to reduce detrimental effects of white-tailed deer populations on white pine seedling success.

Eastern White Pine Forests

Extensive stands of white pine once covered large areas of the northeastern United States (Figure 1), covering over 13 million ha at its peak (Harlow 2001). Logging of this species played an important role in the settlement of the northern region, and became one of the most valuable renewable resources. This expansive range dwindled during the late 1800's to the early 1900's. Pressures from logging practices and the encroachment of settlement reduced acreage of eastern white pine trees (Harlow 2001). Already degraded, these stands encountered additional stresses that exacerbated its struggle. White pine blister rust, a fungus native to Asia, was able to drastically reduce large populations of eastern white pine. Eastern white pines are highly susceptible to the fungus, which is dispersed by windborne spores, allowing it to spread over large areas. The result was a mosaic pattern of already isolated patches further from each other. However, the fragmentation caused by white pine blister rust is minimal compared to the devastating effects caused by the increased presence of white-tailed deer in the region (Vogt, personal communication 2003). The increase in fragmented patches of forested area and the elimination of predator species has enabled dense populations of white-tailed deer to enter the eastern white pine range where they historically did not reside in large numbers.

Figure 1. The range of the eastern white pine (United States and Canada). From Wendle et al. 1990.



Today, white pine forests only cover about 7 million ha and have declined more in Minnesota then anywhere in the nation (UMN FR Co-op). To illustrate, Minnesota once had twice as many white pine hectares as New Hampshire, but now has only $1/20^{th}$ as many. Minnesota now only accounts for 1% of the nation's total white pine lumber production (MFRC 2000). The few remaining stands face perilous stresses because of the high mortality rate in young seedlings caused by lack of viable local seed, browsing, and disease.

Growing concern for the quality and quantity of the eastern white pine in Minnesota mounted in the 1990's. Restoration projects are a routine part of management programs for government lands within the eastern white pine range. In 1996, The Minnesota Department of Natural Resources appointed the White Pine Regeneration Strategies Work Group to fulfill regeneration needs and compile a report along with future recommendations on eastern white pine plantings within Minnesota. This recommendation stated that any government land falling within the eastern white pine range must set targets to increase the presence of the species (WPRSW 1996). Restoration projects that started in the state were compliant with these goals. However, monitoring of eastern white pine seedlings in restoration projects showed a high mortality rate attributed to degradation caused by the increased presence of white-tailed deer. The availability of winter forage and relatively low browse height make eastern white pine seedlings an ideal food source. Minimal amounts of browsing may be beneficial to forest ecosystems; however, the increased population density in winter months and the overall abundance of deer populations in the northeastern regions of the US have led to destructive browsing levels. The increased deer population has initial restoration projects facing difficulties in regeneration. Since manipulating deer populations to lessen densities and presence is currently not be implemented, eastern white pine restoration coordinators must rely on preventative measures to reduce browsing impact.

White-tailed Deer

White-tailed deer are a considerable stressor in restoration projects because they will browse eastern white pines before other pines. Therefore, their forage needs, habitat requirements, and biological activity need to be understood to effectively manage for seedling success. White-tailed deer tend to move between summer and winter ranges for food, mating, and rearing young. In the spring and summer, they migrate towards early deciduous successional forests adjacent to unforested areas. Their primary diet consists of buds, twigs, and shrubs, as well as grasses, and herbaceous vegetation. All of the aforementioned vegetation is plentiful in early successional forests dominated by deciduous vegetation (Voigt et al. 1997). Anthropocentric changes to the landscape such as edged areas around agricultural fields have created ideal spring and summer habitat for the white-tailed deer. As settlement moved northward, the island effect allowed white-tailed deer to move into areas not previously inhabited with high deer population densities. This movement was directed towards the range of the eastern white pine forests. Increased deer presence directly affected this ecosystem, most profoundly by heavy browsing.

In winter, white-tailed deer migrate to coniferous woods for many reasons. Deep snow travel is difficult for white-tailed deer because they have skinny legs with pointed hooves beneath a large torso. Coniferous forests provide adequate dense canopy with their evergreen foliage (needles) intercepting the snowfall that reaches the forest floor. This lessened snow accumulation allows the white-tailed deer to move easier in high snow months. Coniferous forests also provide invaluable source forage when other food sources are limited. After the deciduous trees have lost their leaves, the conifers can supply up to 14 percent of the deer's total diet in the winter months, with 90 percent of that coming from eastern white pine (Aldous 1939). There are currently less available resources per capita since white-tailed deer populations are at historic highs in the region and eastern white pines are lesser in numbers.

Understanding this relationship is imperative when considering restoration projects. Large herds and high deer browse damage are especially acute in parks and natural areas where hunting is prohibited and natural predators are minimal (Miller et al. 1992; Griard et al. 1993; Ward et al 1999). Increasing levels of white-tailed deer populations and densities will intensify the effect they have on the eastern white pine forests.

Different food sources, predation, human interaction, and climate have all played a role in the fluctuation of white-tailed deer density. Current manipulation of all of these factors has created historically high deer populations. The Minnesota Department of Natural Resources (MNDNR) began studying deer populations in the 1970's. The data collected suggests that there is the overall abundance of white-tailed deer in Minnesota's forested regions, and that these populations are becoming denser. The MNDNR Division of Fish and Wildlife modeled approximate deer densities for each of the 37 permit areas located in the forested zone (Northeastern) of Minnesota. When comparing densities of deer per square kilometer from the year 1989 with those of 2002, all but nine areas experienced an increase in density (Figure 2). Area 247 had the greatest amount of increase, with a change of 18.1 deer per square kilometer in the years 1989 to 2002 (Figure 3). (Lenarz 2001)

Figure 2. Comparsion of pre-fawn densities per square kilometers between the years of 1989 and 2002. Data from Lenarz, (2001).

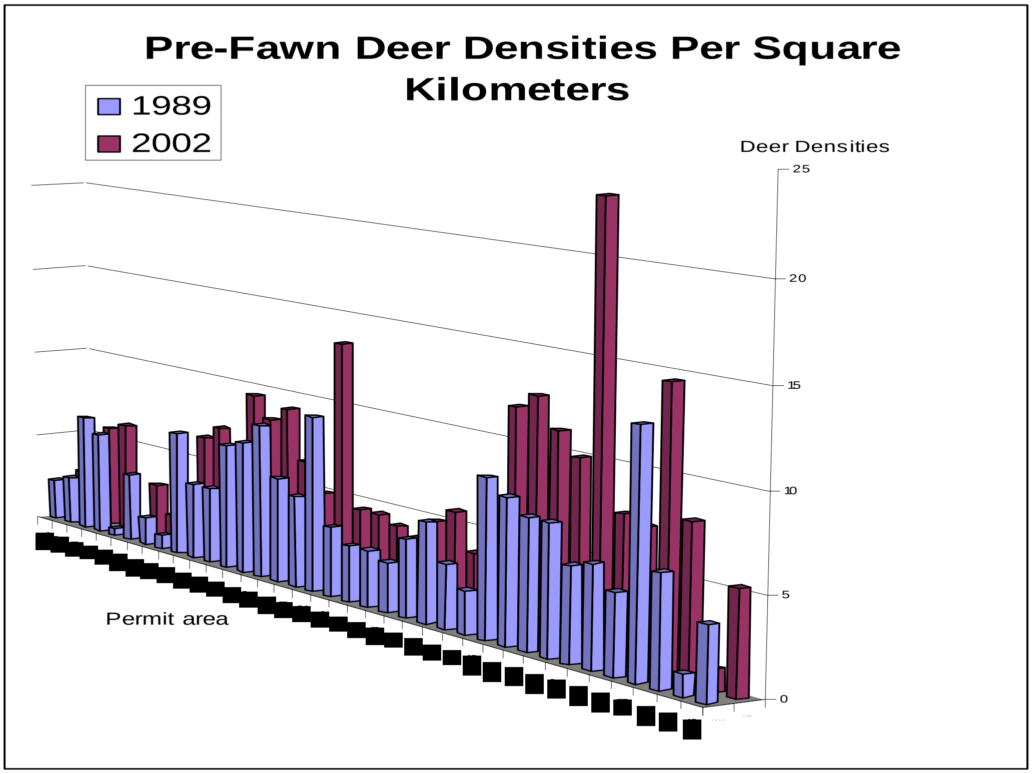
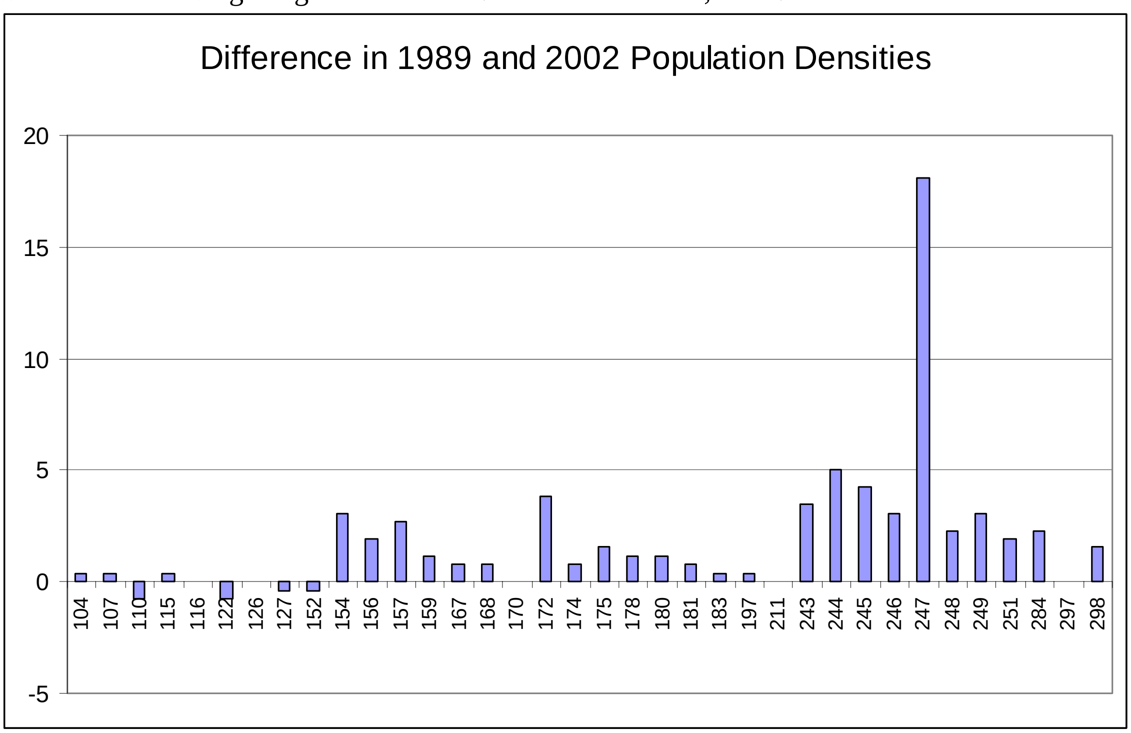


Figure 3. The difference in population densities illustrating that all but nine areas experience an increase, with area 247 having the greatest amount. Data from Lenarz, 2001.



Historically, deer populations have been kept lower in the forested zone due to predation by major species such as the timber wolf (*Canis lupus*) and lack of favorable habitat. During the early 1800's through the early 1900's, there was a major push to eradicate the wolf from Minnesota; the repercussions of these actions were not then evident. When the timber wolf was virtually eradicated from its natural range in Minnesota, the deer population increased. As the deer numbers began to increase, the need for an abundant food source also increased, furthering the stress put on eastern white pine seedlings that are planted in restoration projects.

White-tailed Deer and Plant Communities

White-tailed deer interact with plants and greatly affect their distribution and abundance. They act as keystone herbivores, restructuring entire ecological communities both through their direct and indirect actions (Rooney et al 2002). This has been demonstrated by comparing vegetation in regions with and without deer, and by the use of deer fencing as a model in populated areas. These types of analyses have shown that deer have an effect on the composition of species by reducing favored species, while unfavored species are allowed to proliferate.

White-tailed deer directly affect a plant by browsing, which encompasses all forms of above ground feeding of woody plants such as stripping bark from woody plants and removing twigs, shoots, leaves, needles, buds, or flowers (Danell et al. 2002). These actions are especially detrimental to eastern white pine primarily in the winter months due to larger herd density. The effects of browsing can be increased or decreased depending on the density of the deer population, which is of particular concern under the current population levels. If these levels continue to increase, the detrimental effects on eastern white pine will also increase. A study conducted in northern Minnesota by Saunders and Puetmann (1995), illustrated the effects of browse type feeding on eastern white pines. On average, 38% of all seedlings on the site showed signs of browse damage, with 17 % of all seedlings sustaining terminal leader damage within a year. This high amount of damage was on a site that did include some preventive deer measures, anticipating that this number would be larger if preventative measure were not employed. The data also showed that deer often selected previously browsed seedlings over other types of growth (Saunders et al 1995). This type of sustained browsing by white-tailed deer directly causes sparser stands due to failure in seedling regeneration (Stromayer et al. 1996).

White-tailed deer also indirectly alter plant communities by browsing and behavior. Plants will die if they cannot compensate for deer browsing. Selective browsing by deer leads to a change in species composition by changing vertical structures, microclimates, and nutrient cycling. Herbs are vulnerable to ungulate browsing, as they never grow large enough to escape from browsing height (Rooney et al 2003). The productivity of herbs and grasses in the understory is driven by the amount of available light on the forest floor. Thus there are strong interactions between ungulate population dynamics and the dynamics of herbs, grasses, shrubs, ferns, and trees and the succession of plant species within a given area (Kramer et al 2003).

Sustained browsing by white-tailed deer indirectly affects eastern white pine by altering the understory. This creates conditions that favor grasses, sedges, and ferns, and inhibiting tree regeneration by limiting resources available to seedlings (Avril et al. 2002). Constraining resources cause the eastern white pine to remain in browse height for a longer period of time, about five feet or lower. This has two adverse affects on the growth and survival. One, the seedling allocates carbon to repair browsing injuries and cannot concentrate on vertical meristematic growth (Kimmins 1997). Secondly, the continual injury sustained from heavy browsing and the repair process produces a cycle that inhibits the chance of not only growing out of browse height, but ultimately its survival as well (Aldous 1939). Studies done by Rooney and Waller (2001) illustrated that though some light browsing may be beneficial, most plant species react negatively to heavy browsing. The studies also concluded that the majority of the eastern white pine seedlings planted had complete failure of regeneration or low seedling count as local browsing levels increased (Rooney et al. 2003).

Coniferous and deciduous trees respond differently to browsing. Compensation from browsing is species specific and generally has less detrimental effects on deciduous species (Saunders et al. 1995). This difference is due to two main contrasting aspects of their physiology. First, storage of nitrogen in the needles makes conifers more susceptible to browsing. When the needles are removed, the pines have less nitrogen available for remobilization. Second, eastern white pine has a fixed pattern of growth, whorled sets of braches arranged vertically, where most deciduous trees have an indeterminate growth form with many shoots of new growth throughout tree, allowing for compensatory growth where concentrated browsing has occurred (Danell et al. 2002). This difference in response to browsing further indicates that eastern white pine may be more affected by an increase in white tail deer populations than other woody deciduous species

Bakken and Cook (1998) further illustrate how browsing can favor the development of hardwoods over softwoods. The study site showed a relative abundance of hardwood species in the understory including red maple (*Acer ruburm*), sugar maple (*Acer saccharum*) and basswood (*Tilia Americana*). Bakken and Cook attribute this phenomenon to three factors: (1) moderately high deer densities in the past 10-15 years, (2) the importance of woody browse in winter and early spring and (3) the capacity of different species to endure browsing (Bakken et al. 1998). Late successional hardwood species that are more browse tolerant take less time reaching the forest canopy under browse conditions (Seagle et al. 1997). Continued rapid growth of understory hardwoods resulted in a closed canopy, which directly suppressed the height and diameter of the eastern white pine seedlings. The continued suppression from competition made eastern white pine trees more susceptible to longer periods of browsing (Saunders et al. 1997).

White-tailed deer exhibit inflict other damage to young eastern white pine trees, besides browsing. Excessive trampling can have a negative impact on seedlings by matting them into the soil or destroying tissue in the plant during this fragile time. During mating season mature male deer rub their antlers on trees to get rid of the furry outer layer, known as velvet. This action injures or destroys the bark of the tree, affecting the cambium layer (Haarstad personal communication 2003). The cambium layer is imperative in the transport of nutrients and water within the tree. Depending on the severity the injury, the tree may suffer deformation or eventual death.

Restoration options

Currently, though the efforts of private and resource management agencies, the decline of the eastern white pine has leveled off, with new efforts underway to bring back it back in greater numbers. (DNR 2003) There are several different impediments to restoring eastern white pine under current conditions however. Lack of viable seed sources, increased competition due to altered ecosystems, and denser deer herds are some issues that will need to be addressed in restoration plans.

The amount of land in Minnesota formally occupied by eastern white pine (13 million ha) has dwindled to about 6 million ha due to management practices and land use changes. (DelGiudice et al. 1996) This reduction led to a landscape wide reduction of viable seed, and has been widely recognized as one factor influencing the dramatic decline in this once proliferating species (Mitche. et al. 2002). Due to scarcity of viable seed, management has shifted attention towards retention of seeds and monitoring of seedling success; with the ultimate goal being the protection of established seedlings from death (Mitchel et al. 2002). With this in mind, projects on government lands under the jurisdiction of the White Pine Initiative are implementing deer prevention as a method of restoration. While the number of both individual plantings and pruning for eastern white pine blister rust decreased from the years 1998 to 1999, implementation of deer prevention methods increased (MFRC 2002).

There are several different options that can be implemented in restoration efforts to protect seedlings from white-tailed deer. They range from physical barriers (whole tree or terminal leader) to manipulation of forest ecosystems that indirectly enhance seedling success. Artificial regeneration can become expensive when browse protection is involved, but it may insure long-term feasibility of the restoration project (Kays, 1996; Ward et al. 2000). To insure seedling success, protection methods should be used when seedlings are newly established, 2 years or less, and until the seedling is out of browse height, about 1.5 m or more. Listed below are different options that can be incorporated in restoration efforts, starting with physical barriers and then exploring ecosystem manipulation. For an illustration on the different methods that were used on state lands in accordance with the White Pine Initiative and how much each was implemented (Figure 4 and 5) . The important thing to note was the increase in use from 1998-1999, and that bud capping was the implemented the most (Lenarz 2001).

Figure 4. The silviculture practices used in the prevention of deer browse in the years 1998 and 1999. Data from MNDNR-DF 2002).

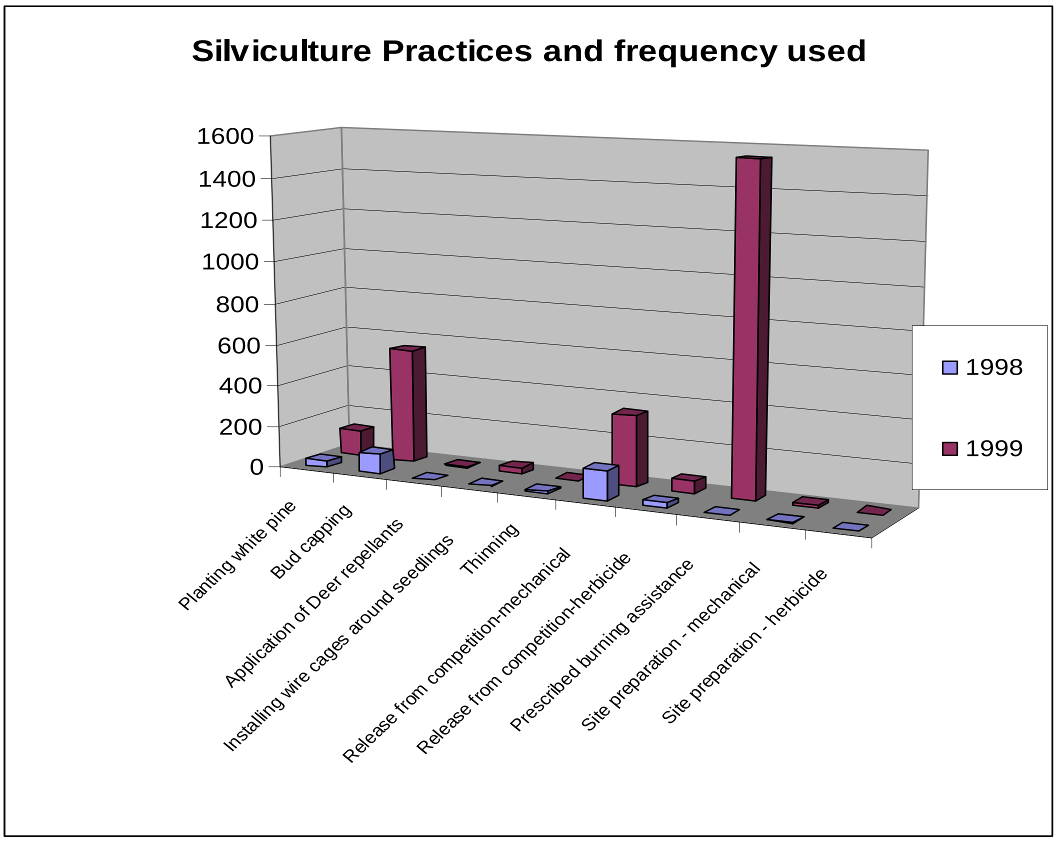
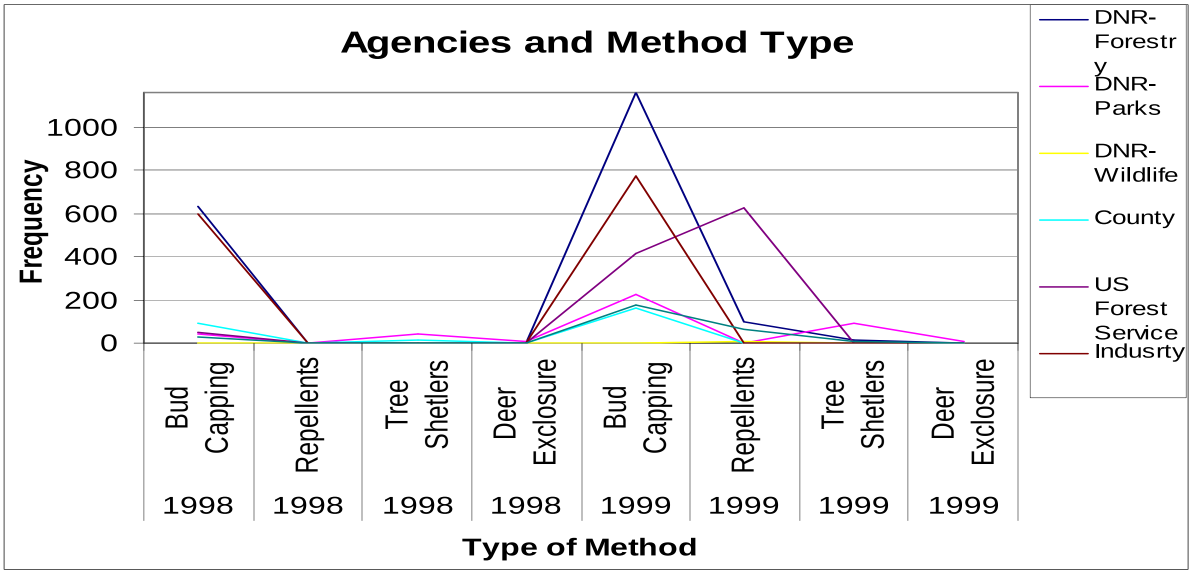


Figure 5 The different agencies and what mode of protection they used in the years 1998 and 1999. Data from MNDNR-DF (2002).



Protection Methods

Protection should be used if signs of deer browse are prevalent. Browsing of new growth usually leaves a clean break that will callus over as the twig heals. Older more mature woody vegetation during the dormant season will have a more jagged or splintered stem. If browsing occurs in spring the bark may fray and leave the stripped stem some distance from the actual break. Fall is the best time to evaluate if deer damage has occurred because the grasses and other deciduous plants have died back making the seedlings easier to see (Duddles et al. 1999).

Bud capping. Bud capping focuses on protecting new growth, mainly on the dominant apical meristem of young trees (Barnacle 1997). This process involves the use of a small piece of weatherproof paper that is folded in half and placed around terminal leader and then stapled, enclosing the bud. The paper sheath prevents consumption of the enclosed bud by deer. Bud caps should be reapplied every fall where high deer populations are a concern (deer browsing is most relevant in winter months) until the tree is out of reach of browsing deer (Duddles et al. 1999). Bud capping shows no signs of limiting seedling height, but may have low incidence of bent terminal leaders in areas of strong winds (Duddles et al. 1999). This method is highly effective and widely used in many projects where conifer buds are to be protected. The cost of materials for bud capping is relatively cheap and packets are readily available at state natural resource agencies.

Tree shelters. Tree shelters are usually made of biodegradable plastic that is either in the form of a tube or mesh. These are placed around each of the seedlings to protect the tree from browse, and have significantly shown to reduce deer browse mortality and damage in eastern white pines (Ward et at. 2000).

Plastic tubes are rigid plastic that are photodegradable, which are designed to break down in sunlight after 2 to 5 years, usually more quickly on southern then northern exposures. They are extremely effective at detouring browse if installed properly (covering the terminal leader), and can work well at preventing mulitpest feeding damage (Duddles et al. 1999). They may also increase the competitive capacity of seedlings because they offer protection from the elements. There are some cautions about using plastic tubes however. These tubes can be difficult to install on already planted and established seedlings, and require site maintenance to insure they are straight and that the terminal leaders are not tangled from growing through the tube (Duddles 1999). Other precautions include a weaker tree trunk due to the increased heat with in the tube causing increased seedling growth, lowered aesthetic value, and the need for removal of the shelters after seedlings have reached a desired height if they have not degraded. (Vatovec 2001)

Meshes are installed and function similar to the plastic tubes. They have three main benefits over the tubes. One, they do not create microclimates that may cause weak trunks or lack of ventilation. Second, they may not be as aesthetically displeasing because they are not as opaque. Thirdly, they may have the potential to break down faster due to the increased surface area being susceptible to light. One caution about mesh is in the removal stage. The removal can be cumbersome because the branches of the trees as they grow have to potential to get caught in the mesh (Duddles 1999). Due to the longevity of tree shelters, lasting several years, site visits are less than needed in bud capping. There are many companies that supply different types of tree shelters and most are widely available for restoration projects.

Deer enclosures (fencing) Deer enclosures are used when protecting entire plantations, trees of high value, or when reforesting by any other means is not possible. The most common type of fence used is a woven wire fence, similar to that of pig fencing, and can be electric or non-electric (Duddles 1999). This method often requires more time and is costly to implement, especially in rough terrain, but is every effective in physically keeping deer away. Proper installation requires the fence to be low enough (usually protruding into the ground) so that deer are unable to crawl under, and should be tall enough that they cannot jump over it. Physical removal of deer is most pertinent on browse selected or browse intolerant species or ecosystems (Vatovec 2001).

Repellents. Deer repellents are substances (solution, spray, powder, or capsule) that deter deer, by either taste or smell, from eating or browsing the buds of a seedling to which it has been applied. They include bone meal, egg solids, or chemically derived substances that usually have a latex sticker to make them rain resistant (Duddles 1999) The longevity of the deterrent depends on the chemical used, and ranges from two months to one year (MFRC 2002). A potential concern with this method is that the repellant often needs to be applied several times a year, increasing site visits and management costs. To reduce the duration of visits to the protected area, there are clip-on style repellents that snap onto shoots of young trees and offer protection from browsing for six to eight months (Forestry Suppliers 2003). These have been used with some success but are not recommended for saplings due to the weight of the repellent stick. The tips of the tree can bend under the weight and cause injury to the tree (Smith et al. 1997).

Ecosystem manipulation

Forest ecosystem manipulations are done with the goal of promoting eastern white pine seedling advantage within the current altered state. This includes insuring a greater amount of available resources that allow the seedling to grow quicker out of browse height, or to lessen the impact of browsing on the seedlings. Ecosystem manipulation includes prescribed burning, selective crown thinning, planting higher quality seedlings, and removal of competing vegetation (mechanical and herbicidal). The natural eastern white pine forest ecosystem is then allowed to regenerate when the seedlings are no longer threatened by browsing.

Manipulation of the current forest structure after heavy browsing is essential in contributing to the success of regeneration. Partial removal of overstory trees to eliminate the canopy enclosure helps seedlings to propagate with the occurrence of browsing (Saunders 1999). This increase of light to the forest floor can also increase competing vegetation, so other techniques must be used in collaboration with this action. Grass, ferns, and sedge populations must be decreased or removed in order to achieve eastern white pine seedling success. Mowing, cutting, uprooting, prescribed fire or herbicides can be used in managing the understory brush (Smith et al. 1997). Study plots at the Cloquet Forestry Center located in northern Minnesota showed greater success in eastern white pine seedling in the sites that were "tilled" then in other types of disturbance (Lecture, Severs, October 3, 2003).

Eastern white pine is not as shade intolerant as once thought so it is necessary to examine the amount of removal of understory brush before taking on wide-scale restoration efforts. By keeping some horizontal and vertical cover, the seedlings are hidden from deer, which decreases the probability of browse (Saunders 1999). The use of planting species more palatable to white tail deer may also be an option. The intermixed seedling plantings could occur on the outer edges of reforested areas containing eastern white pines. The theory behind this is that the white-tailed deer will browse upon the more appealing planted species and not the eastern white pine seedlings in the forest.

Release from competition (mechanical). Mechanical release (also known as liberation) from competition within forested ecosystems involves the manual removal of competing plants both woody as well as herbaceous. This removal reduces competition that young eastern white pine saplings experience on the forest floor. For this particular method to be effective and implemented correctly, a forest inventory should be made in order to protect key species in the forest along with the trees that are to be released.

Release from competition (herbicides). Herbicidal release operations can free young desirable trees from competition and suppression within a forested area. This method utilizes a chemical application to the foliage and stems of herbaceous and woody plants. In relation to eastern white pine trees, release methods must be done carefully to avoid 'burning' the delicate foliage of the trees that are near targeted areas. The most common and effective herbicide used in release operations is Picloram. This herbicide in particular contains an amine salt that is readily absorbed by leaves as well as roots and can be sprayed or injected depending on situational application (Smith et al. 1996). Picloram is very low in animal toxicity but can remain at the site of application for about one year (Smith et al. 1996)

Prescribed burring. The role of prescribed burning and the eastern white pine tree is a delicate and complicated process that should be implemented by trained individuals. Eastern white pine trees by nature have a thin outer bark with the cambium layer especially vulnerable to disruption and damage, therefore the rate of fire occurrence should be site and spacing specific (J.Haarstad personal communication 2003). In restoration of eastern white pine trees, fire is used to clear the understory of excess woody growth and litter to provide for a good seedbed by adding essential nutrients released in the burn. The fires usually used in eastern white pine forested areas are of low intensity; meaning the rate of duration and heat from the fire is minimal. It is important that a particular prescribed fire frequency is followed due to the volatility specifically related to eastern white pine trees and other conifers.

Planting high quality seedlings. Planting quality seedlings that are larger rather then using large quantities of smaller seedlings may be used as an alternative or in collaboration with direct and indirect methods. Larger seedlings are more able to compete and can grow out of browse height sooner (Johnson 1984; Smith 1993; Zaczek et al. 1995; Schuler et al. 1996 Dey et al. 1997; Ward et al. 2000)

Conclusion

The decline of eastern white pine has leveled off through the efforts of resource management agencies, with new efforts underway to restore the previous range (DNR 2003). However, problems from white-tailed deer, disease, competing weeds and shrubs, and lack of a viable seed source still need to be addressed. These issues have put enormous stress on the remaining stands and on the new generation. The most significant of these aforementioned stresses is the increase in white-tailed deer populations in the northeastern forested regions of the United States. White-tailed deer can stress this system of forest ecosystems directly by browsing or indirectly by altering species composition. Since most restoration projects are taking place in a stressed state, many projects are turning to methods of protection rather than only planting seedlings.

Many techniques can be used in restoration projects to assure seedling protection. These can either be in the form of a direct barrier or use forms of ecosystem manipulation. Both types are effective in limiting the damage done by deer browse, but have some cautions as well. Most techniques require extensive management skills and resources, but forest ecosystem manipulation requires the most. Private citizens are often unprepared to implement most of the techniques outlined in this paper. It is suggested that any small restoration done by a private individual should be bud capping or fencing. Bud capping is the less expensive of the two methods and seems to be used most frequently on state owned lands. This technique is also beneficial because it only requires basic skills to execute. The only pitfall is that bud capping requires many site visits to maintain caps on the trees. Fencing works well on small areas because of the expense of fencing material. This type of protection requires fences tall enough that deer cannot jump over it and low enough they can not crawl under. Many individuals are capable of installation and maintenance, and this method does well for the physical removal of deer from an area.

The problem still remains that deer densities are too high for northeastern forested regions of the United States. This will continue to be a problem in restoration until density is lowered. Future restoration plans should encompass all management objectives and incorporate the science of species for the white-tailed deer and the eastern white pine. The managers and scientists need to work together to reach effective and long lasting solutions while considering the effects of white-tailed deer populations on eastern white pine tree restoration.

Literature Cited

Aldous, Shaler E. 1939. Pine in the diet of the white-tailed deer. Journal of Forestry 37: 265-267.

Avril L. de la Cretaz, Mathew J. Kelly. 2002. Development of Tree Regeneration in Fern-dominated Forest Understories After Reduction Of Deer Browsing. Restoration Ecology 10: 416-426.

Bakken, Peter N., Cook, James E. 1998. Regeneration Potential of Six Habitat Types Common to North-Central Wisconsin. Northern Journal for Applied Forestry 15:116-123.

Barnacle. B 1997. Protecting eastern white pine tree seedlings from deer browsing with bud caps Minnesota Department of Natural Resourses Forestry Newsletter No. 6 1997

Dannell, Kjell, Bergstrom, Roger, Edenius, Ericsson, Goran. 2003. Ungulates as Drivers of Tree Population Dynamics at Module and Ganet Levels. Forest Ecology and Management 181:67-76.

Department of Natural Resources,(DNR) (2003). White Pine Planting and Care Guide. St. Paul, Minnesota.

Duddles, R.E., Edge W.D. 1999. Understanding and Controlling Deer Damage in Young Plantations. The Woodland Workbook, Reforstation. EC 1201. Reprinted in June 1999. Organ state University Extension Services.

Ford, William M., Johnson, A., Sydney, Hale, and Philip E. 1997. Influence of Forest Type, Stand Age, and Weather on Deer Weights and Antler Size in the Southern Appalachians. Southern Journal of Applied Forestry 21:11-18.

Forestry Suppliers Catalog. 2003. Number 54, 2003. (pp305-306)

Harllow. 2001. Textbook of Dendrology. Ninth ed. McGraw-Hill Higher Education. (pp108-110)

Haarstad. John. 2003. Resident Naturalist, Cedar Creek Natural History Area Bethel, MN Personal communication, October, 13, 2003.

Keegan, Thomas W., Johnson, Mark K., and Nelson, Billy D. 1989. American Jointvetch Improves Summer Range for White-tailed deer. Journal of Range Management 42: 28-134.

Kimmins. J.P. 1997. Forest Ecology A Foudation for Sustainable Management. second edition. New York Publishing (pp169-172)

Kramer, K., Groen, T.A., and van Wieren S.E. van. 2003. The Interacting Effects of Ungulates and Fire on Forest Dynamics: an Analysis using the Model FORESPACE. Forest Ecology and Management 181: 205-222.

Lenarz Mark. S. 2001. Division of Fish and Wildlife Forest Wild Life Populations and Research Group. White-tailed Deer of Minnesota's Forested Zone: Harvest, Population Trends and Modeling.

Mitchell, R.J, Franklin J.F , Palik B.K ,Kirkman, Smith L.L , R.T. Engstrom, and, Hunter M.L.2002, . Natural Disturbance-Based Silviculture for Restoration and Maintenance of Biological Diversity. Executive Summary 2002.

Minnesota Department of Natural Resources. 2002. Division of Forestry (MNDNR-DF) Implementation of the White Pine Initiative. FY 99 Report to the Minnesota resource council.

Minnesota Forest Resource Council (MFRC). 2003. White Pine Management Recommendations. June 11, 2002. Compiled by Galord Paulsen and Chad Skally. www.frc.state.mn.us/info/mfrcdocs. Accessed Nov. 2003.

Minnesota Forest Resource Council. 1996. (MFRC) Response to the report of the White Pine Regeneration Strategies Work Group (1997) Minnesota's White Pine Initiative Recommendations. Implementations of the White Pine initiative.

Rooney, Thomas P., Waller Donald M., D.2002.Direct and Indirect Effects of White-Tailed Deer in Forest Ecosystems. Forest Ecology and Management 181:165-176.

Saunders, Mike R and Puttman, Klaus J.1999. Use of Vegetational Characteristics and Browsing Patterns to Predict Deer Damage in Eastern White Pine (Pinus strobus) Plantations. Northern Journal for Applied Forestry 16: 96-102.

Saunders, Mike R. and Puettmann, Klaus J. 1995. Effects of Overstory and Understory Competition and Simulated Herbivory on Growth and Survival of White Pine Seedlings. Canadian Journal of Forestry Restoration 29: 536-546.

Severs, Ronald. "Management of the Cloquet Forestry Center" Cloquet Forestry Center Cloquet, MN, October 3, 2001

Smith, D. Larson. B, Kelty, Mark. P., Ashton. S. 1996. The Practice of Siliviculture. Applied Forest Ecology. Ninth ed. (pp142-144)

University of Minnesota, Forest Research center Co-op. (UMN FR Co-op) http://WWW.cnr.umn.edu/FR/research/centercoop/mfric/morego20+tables.htm WWW.cnr.umn.edu/FR/research/centercoop/mfric/morego20+tables.htm. Accessed September 2003.

Vatovec. C 2001. *Odocoileus virginianus* as a Stressor in Forest Restoration. http://www.hort.agri.umn.edu/h5015/00papers/vatovec.htm. Accessed October 2003.

Vogt, Carl. 2003. Associate Professor, University of Minnesota, Personal communication Oct-Nov 2003

Voigt, Dennis R., Bradfoot, Jim D, and Baker, James A. 1997. *Govt. Pub*. Forest Management Guidelines for the Provision of White-Tailed Deer Habitat. Version 1.0 1997 Cette publication technique n'est disponible qu'en anglais.1997, Queen's Printer for Ontario.

Ward, Jeffery S., Gent, Martin P.N., and Stephens, George R. 2002. Effects of Planting Stock Quality and Browse Protection-Type on Height Growth of Northern Red Oak and Eastern White Pine. Forest Ecology and Management 127: 205-216.

Weisberg, Peter J., Hobbs N. Thompson, Ellis, James E., and Coughenour, Michael B. 2001. An Ecosystem Approach To Population Management of Ungulates. Journal of Environmental Management. 65: 181-197.

Wendel, G.W. and H.C. Smith 1990. *Pinus strobus* L., Eastern White Pine, pp. 476-488. *In* R.M. Burns and B.H. Honkala (eds.), Silvics of North America, Vol. 1, Conifers, U.S.D.A. For. Serv. Agric. Handbk. 654, Washington, D.C.

White Pine Regeneration Strategies Workshop (WPRSW). 1996., MN White Pine: Now and for the Future. Report of White Pine Regeneration Stragities Work Group.