Restoration and Reclamation Review
Student On-Line Journal
Vol.6, No.6, Fall 2000
Department of Horticultural Science
University of Minnesota, St.Paul, MN

Odocoileus virginianus as a Stressor in Forest Restoration

Christine Vatovec

Introduction

Successful forest restoration depends on identifying stressors within the system that can negatively impact planting attempts. The stress of animal browsing should be an important consideration in reforestation because it can decrease survival of seedlings and saplings. The browsing pressure of the white-tailed deer (*Odocoileus virginianus*) has been documented as a major stress in forest systems, and can severely damage or even completely destroy reforestation attempts. White-tailed deer directly affect forest regeneration by browsing on seedlings, thus reducing their stem height and ability to compete effectively for available resources (Tilghman 1989, Stange and Shea 1998). Indirect effects occur when browsing causes a change in herbaceous vegetation composition, thereby affecting growth and survival of seedlings (Tilghman 1989). When white-tailed deer become overabundant in an area, they severely damage the plant community by overbrowsing. Too many deer in an area means high competition for food, and the tendency for deer to eat anything they can access. Overbrowsing prevents the regeneration of palatable components of the plant community, thereby affecting ecosystem diversity and the abundance of species (Garrott *et al*. 1993). Several techniques have been suggested to decrease the impacts of white-tailed deer on forest restoration. This paper presents several techniques, and provides information to help restoration managers make informed decisions on practices best suited for a range of restoration situations.

The Importance of Forest Systems

Forest ecosystems are highly valued for several reasons. Locally, forests reduce erosion potential, provide habitat for several species, and help in the natural dispersal of species by providing corridors for travel. Forests are valuable to humans for recreation, and for their harvest potential. Areas that were originally forested but have been degraded, such as agricultural areas and sites of mining operations, hold the potential to be restored to natural, historical forested systems. When preparing for any restoration, it is imperative that all stressors be determined so that the revegetation process can be managed for optimum success. The white-tailed deer has been targeted as having the potential to be a severe stressor in reforestation projects.

Historically, Minnesota's forests covered nearly 32 million acres and were dominated by conifers, mainly white pine (*Pinus strobus*); white-tailed deer were relatively rare in the forested landscape (DelGiudice and Riggs 1996). During the period from 1880 to 1910, logging removed nearly all of the white pine from the forests. The early successional growth of reestablishing vegetation, coupled with only light pressure from hunting and the control of the wolf as a natural predator, allowed the white-tailed deer population to expand. Today Minnesota's forests cover approximately 16.7 million acres, or about half of the pre-settlement land area (DelGiudice and Riggs 1996). The white-tailed deer population has, however, been steadily increasing because of this species' high success in edge habitats, and practices that have allowed for its expansion.

Natural History of the White-tailed Deer

The white-tailed deer is a member of the family Cervidae, distinguished by hoofed animals with antlers that are shed annually (Burt and Grossenheider 1980). This species is characterized by its namesake, a white tail, that the deer flags behind itself when retreating from danger. The white-tailed deer has a reddish fur coat in summer that is replaced with a blue-gray coat in the winter. Average height of this deer is 3 to 3.5 feet (91-107 cm); females weigh between 50 and 250 pounds (22.5-112.5 kg), males between 75 and 400 pounds (33.7-180 kg). Each year the male white-tailed deer grows antlers that are covered in "velvet", a sensitive tissue that supplies blood circulation necessary for growing bone (Raycroft 1999). Prior to the rut, or breeding season, the bucks remove this velvet by rubbing their full-grown antlers vigorously on small saplings. These "buck rubs" (Figure 1) can be detrimental to sapling growth by injuring the tree (Gillette 2000, personal communication). This rubbing leaves saplings damaged with shredded bark, and can slow or be detrimental to growth depending on the severity. The newly exposed bone of the antler is then used for sparring between bucks to determine dominance and thus breeding rights.

Figure 1.

Preferred habitat for this species include forests, swamps, and open brushy areas nearby. The white-tailed deer is considered a browser, eating the tips off twigs and shrubs. They also feed upon fungi, acorns, grasses and herbaceous vegetation (Burt and Grossenheider 1980). During the winter, the white-tailed deer tends to group in herds of 25 or more animals. In especially severe winters, this herding can greatly impact areas where the deer browse heavily on available vegetation and strip the bark from tree species as a forage source.

The white-tailed deer is the most widely distributed mammal in North America today (Raycroft 2000). They can be found in every state within the contiguous United States, north into Canada, and south into Mexico. This species is very adaptive, surviving successfully within a human-altered landscape. The white-tailed deer is one of the most important big game mammals in its range. Management of this species has typically favored landscape uses that promote large deer populations. Large populations provide increased hunting opportunities, but can also inhibit forest regeneration and restoration.

Population increases and the problem of overabundance

Populations of white-tailed deer have increased from historic numbers due to loss of predators (the gray wolf, *Canis lupus)*, population management for sport hunting (Hiller 1996; Coffey and Johnston 1997), and land management practices that provide edge habitat. Practices such as logging, development of roads, houses, and agricultural land has resulted in an increase in habitat edges, the area where two habitat types meet. Environments that have been altered by humans in such a way tend to favor a sub-set of native species that easily adapt to these changes, resulting in expansion of their populations (Garrott *et al.* 1993, Meffe and Carroll 1997). Commonly, their expansion is to the detriment of other native species. These overabundant populations can reduce natural diversity by changing species composition and relative abundance, and can result in local extinctions of other native populations. The white-tailed deer has become overabundant, and tends to prefer edge habitats where, for example, forests and farm fields meet thus providing adjacent cover and food sources.

Restoration Management Options

Forest restoration managers should consider the possible effects of white-tailed deer on planting success, and respond accordingly with the use of techniques that will limit browse effects. According to Larry Gillette (2000, personal communication), Wildlife Manager of Hennepin Regional Parks, newly planted vegetation is more attractive to deer than established plants. Newly planted vegetation remains succulent longer than surrounding vegetation, thus remaining palatable longer. The restored vegetation will be most vulnerable during the first two years or so until it adjusts to natural cycles, thereby leafing out and senescing at the same time as surrounding plants. Therefore, the first two years will be the most important time to protect restored vegetation from possible white-tailed deer damage. Various techniques have been proposed for limiting white-tailed deer damage to forest restoration projects, including the use of synthetic repellents (Palmer et al. 1983), predator urine (Swihart et al. 1991), dogs (Beringer *et al*. 1994, Cornell University 2000)**,** tree shelters (Stange and Shea 1998), exclosure fencing (Opperman and Merenlender 2000), using various planting strategies (Gillette 2000, personal communication), and managing the deer population (Coffey and Johnston 1997; Augustine and Frelich 1998; Gillette 2000, personal communication).

Chemical repellents

In areas where other forms of control are impractical, chemical repellents are often used (Swihart *et al.* 1991). Chemicals can be either taste or odor repellents, and are applied either in a liquid form with a sprayer or in a powder form and sprinkled on the ground surrounding a plant or placed in cloth bags and hung from seedlings to disseminate their scent (Cornell University 2000). Both synthetic repellents (Palmer *et al*. 1983) and predator urines (Swihart et al. 1991) have been used to deter browsing by white-tailed deer in restoration projects. Palmer *et al*. (1983) studied the effectiveness of various synthetic repellents on controlling white-tailed deer damage (Table 1). Over four trials, only “Big Game Repellent” was consistently found to reduce deer feeding as compared to the control.

Table 1. Seven synthetic chemical repellents to deer damage and the average number of seedlings browsed over four trials (n=40 seedlings in each trial; adapted from Harris *et al*. 1983, Palmer *et al*. 1983, Cornell University 2000).

Repellent	Effectiveness (% unbrowsed)	Active Ingredient (%)	Cost/gallon (cost/3.79 L)	Coverage/gallon (coverage/3.79 L)	Application process	Original use
Big game	78.2	Putrescent egg solids (37)	$26	100-150 seedlings	Liquid spray	EPA registered repellent
Hinder	59.4	Ammonium soaps of higher fatty acids (15)	$40	1 acre (.4047 ha)	Liquid spray	EPA registered repellent
Spotrete-F Flowable Fungicide	34.4	Thiram (42)	NA	NA	Liquid spray	Turfgrass fungicide
Feather Meal	31.9	Ground chicken feathers (100)	NA	NA	Place in cloth bag, hang from seedling	Home remedy
Meat Meal	31.9	Tankage (100)	NA	NA	Place in cloth bag, hang from seedling	Home remedy
Hot Sauce	27.5	Capsaicin (2.5)	$80	8 acres (3.2376 ha)	Liquid spray	EPA registered repellent
Control	20	NA	NA	NA	NA	NA

Predator urines can also be a repellent to damage-causing deer. Their effectiveness depends on factors such as whether or not the predator and prey occur sympatrically in the ecosystem, and the duration of this association (Swihart *et al*. 1991). A study by Swihart *et al*. (1991) comparing three predator urines found that bobcat urine was the most effective repellent, followed by coyote, and finally human urine. It is important to remember that the effectiveness of any chemical repellent may be influenced by factors such as climate and the frequency of application. Gillette (2000 personal communication) recommends applying chemical repellents every two weeks for the first few months after planting, and then reducing application to once a month, with the repellent being necessary for only the first two years or so until the vegetation becomes well established**.** However, the feasibility of application frequency will vary with scale of the restoration.

Dogs as deterrents

Domesticated dogs can be used as a deterrent to browsing deer. By keeping dogs within the restoration area, deer will be less likely to browse in the area because of the instinct to stay away from predator type animals. A study comparing the use of dogs to deter browsing deer with a chemical repellent found dogs to be an effective way to limit deer damage to a forest restoration site (Beringer *et al.* 1994). Average browse rates over a three-year study were 13% in the dog-protected area, 37% in the chemical repellent area, and 56% in the control area. Also, the mean weights of browsed seedlings were heaviest in the dog-protected areas, suggesting a lower severity of browse in these plots. It is suggested that the dogs be kept within the restoration area by using invisible fencing (Cornell University 2000). This requires a dog collar equipped with a sensor that shocks the animal when it approaches the perimeter of the "fenced" area. This technique would not be suggested for remote areas because of necessary animal care.

Tree shelters

Protecting individual seedlings and saplings by using tree shelters has been shown as useful tool in limiting white-tailed deer pressure on restoration projects. Stange and Shea (1998) showed that seedling mortality was greatly reduced when tree shelters were used. Their experiment of survival in red oak (*Quercus rubra*) seedlings resulted in a mortality of 34.6% of unsheltered seedlings, as compared with only 3.2% mortality of seedlings protected with shelters. Though this technique is very effective, it is also expensive so the scale of the project should be considered before choosing this option (Gillette 2000, personal communication). Other concerns include aesthetic value of the site, the need for removal of shelters after seedlings have reached the desired height, and a lack of ventilation that may occur within shelters (Johnson 1997**)**. This lack of ventilation may increase the initial seedling growth rate by providing heat, possibly resulting in a weaker tree trunk in the future. A possible alternative material to the hard plastic shelter is mesh, which will allow for ventilation, but may require extra time for removal as branching through the mesh may occur as the seedling grows (Johnson 1997).

Exclosure fencing

One of the most effective ways to protect plantings is to physically keep deer out of the area by using exclosure fencing. A long-term study of deer exclosure effects, conducted in Minnesota's Itasca State Park beginning in 1946, showed a great reduction of deer browse impact as a result of fencing (Table 2; Ross *et al.* 1970). Another study focusing on deer herbivory effects on riparian restorations, concluded that an exclosure fence eliminated deer from an area, allowing vigorous regeneration of browsed species including willows (*Salix exigua, S. laevigata, and S. lasiolepis*), alder (*Alnus rhombifolia*) and ash (*Fraxinus latifolia*; Opperman and Merenlender 2000). Anderson and Katz (1993) found that certain browse-sensitive species can recover when intensive browsing is eliminated. Fencing may be a good way to help such recovery.

Fencing can be very expensive and may require maintenance, therefore it may be most cost effective to use exclosure fencing only at large restoration sites (1 to 20 acres, .40 to 8.1 ha; Gillette 2000, personal communication; Cornett 2000, personal communication). Fences should be built at a height of 12 to 15 feet (3.7 to 4.6 m); tall enough so deer will not be able to jump the fence. To avoid damage from falling trees, Cornett (2000 personal communication) recommends including two strands of wire along the top of the fence to decrease the impact of falling trees on the fence itself. This will limit the maintenance of the fence itself, but these wires should be repaired quickly to avoid future damage. In areas such as the North Shore of Lake Superior where snowshoe hare (*Lepus americanus*) are also a browsing stressor in forest restoration, Cornett recommends burying the wire to eliminate hare from the exclosure area, as well as deer.

Another fencing option is to focus on restoring small areas within the proposed site (Cornett 2000, personal communication). The advantage to this is a smaller requirement for fencing which may be easier to repair, and less daunting to restoration managers. It is also recommended that preliminary fencing projects be used to determine if deer pressure is limiting restoration success (Opperman and Merenlender 2000).

Table 2. Number of red (*Pinus resinosa*) and white (*P. strobus*) pine saplings per hectare inside and outside a deer exclosure (adapted from Ross *et al*. 1970)

Year	*Pinus resinosa*		*Pinus strobus*	
	Inside	Outside	Inside	Outside
1946	47	0	1433	0
1948	84	0	1740	12
1950	99	74	2051	59

Planting strategies

Hennepin Regional Parks recommends planting large areas (greater than 20 acres, 8.1 ha) all at once in a restoration project (Gillette 2000, personal communication). This can be advantageous in two ways. First, large plantings can overwhelm the deer population and although browsing may damage part of the planting, the majority will escape deer damage. Second, deer tend to be territorial in the summer and it is less likely that a large area will be totally encompassed within the population's browsing territory.

Another option put forth by Gillette (2000, personal communication) which deserves further investigation is to plant "weeds" along with the desired vegetation. This may include herbaceous species that would be more succulent and desirable as forage for deer, thus allowing the restoration vegetation to escape deer damage. In a study of understory herbaceous plant communities, Augustine and Frelich (1998) found that deer focused their grazing on large, reproductive plants. This provides two insights to restoration managers. First, that creating a healthy understory plant community will require protection of herbaceous species, and particularly spring ephemerals that will become available as forage before other species. Second, that the availability of such plants may decrease browsing impacts on establishing woody species.

Another planting strategy is to use well-established species as cover to facilitate establishment of species that are heavily favored by browsing deer. Borgmann *et al*. (1999) showed that stands of balsam fir (*Abies balsamea*) create a physical or visual barrier to deer, thus providing refuge to eastern hemlock (*Tsuga canadensis*) seedlings. Research determined that hemlock saplings were three times as dense and twice as tall when growing in balsam fir patches as compared to saplings growing outside such patches.

Managing white-tailed deer populations

Population control is the most controversial management option for controlling white-tailed deer pressure on restoration plantings (Coffey and Johnston 1997; Augustine and Frelich 1998; Gillette 2000, personal communication). It is also the most necessary option to ensure future survival of forest ecosystems. The other methods outlined in this paper will help manage deer related problems on a site-specific basis, but may just lead to increased deer damage at other locations (Cornell University 2000). Eventually some form of population will be needed to maintain the deer population within the carrying capacity. Deer populations can be controlled by hunting, relocation of animals, and fertility control using contraceptives (Coffey and Johnston 1997). Management of a deer population is a large scale option that requires a large land area and the involvement of several stakeholders and agencies. The population level needs to be accurately assessed to determine whether or not the herd size suggests overabundance in the area. It is important to note that winter population size is a determinant of whether or not increased damage will occur at a restoration site. White-tailed deer tend to herd in the winter, reaching concentrations that differ greatly from summer abundance within the same area (Augustine and Frelich 1998). In a particularly harsh winter with deep snows, deer may be forced to stay heavily concentrated within an area, eating everything they can access including stripping bark off trees and saplings. Therefore, winter counts of an area may find 30 to 35 deer per square mile (258.998 ha), whereas summer counts may find a density of only 10 to 15 deer. It is also important to include deer-car collisions and neighbor complaints about deer when determining a suitable deer population for an area (Gillette 2000, personal communication). After the deer population size has been determined, and a recommendation for a suitable population size has been made, hunting permits may be issued. The resulting decrease in deer numbers in an area will cause lower browsing pressure on vegetation.

Techniques Being Researched

Shea (2000, personal communication) has been researching the use of covers over each individual seedling/sapling tip to deter browsing. This method consists of stapling white index cards together and placing them over the tip of each individual twig of a seedling. Though no statistical analysis has been completed to determine success of this technique, Shea believes that the deer are not browsing on the covered tips, and may actually be scared away from the seedlings because of the white flash produced by the index cards. If continuing research shows that this is an effective treatment to discourage deer browse, it may be a less expensive technique than tree shelters, but may require greater maintenance to ensure continued success.

Summary and Recommendations

Several techniques have been suggested for decreasing the impact of white-tailed deer on forest restoration projects. Many considerations must be made before choosing a technique that is suitable for any particular reforestation site. Managers must determine the potential for white-tailed deer to negatively impact the success of reforestation efforts. Also, the size of the site and funding availability must be included in assessments of technique feasibility. Chemical repellents can be a useful deterrent to deer browsing, but cost and the possibility of needing chemical reapplication are important to consider. The use of dogs can help physically keep deer out of an area, but the dogs must be cared for, so this would not be recommended for distant locations. Tree shelters have been documented to protect seedlings to an age when they are at less danger of being severely damaged by browse, but again this technique can be costly at larger scales, and may cause stems to be weak from early growth directed by heat within the shelters. Exclosure fencing has also been shown to successfully keep deer out of an area, but maintenance is required, and again the scale of the project can affect the cost of building and repairing the fence. Planting large areas (greater than 20 acres, 8.1 ha) can help ensure that some seedlings will survive deer browsing, but this may require future replanting if certain areas within the site are completely damaged. Also, hand planting may be more helpful in reducing deer browse by eliminating the creation of rows of seedlings which deer can easily follow along, clipping off every bud.

Management of the deer population can ensure that the population size does not exceed the carrying capacity by eliminating a situation of overabundance and the tendency of deer to eat anything they can reach if the circumstances are dire. However, this is a long-term commitment and requires the cooperation of multiple stakeholders and government agencies. Though management of the deer population is the only way to ensure the long-term success of forest restoration, the techniques outlined in this paper are proposed to help managers choose options that will help in immediate restoration efforts. For small sites, I would recommend the use of tree shelters as being the most efficient way to protect forest plantings. For larger sites, I recommend exclosure fencing. However, if costs of construction and maintenance make this technique infeasible, I recommend restoration efforts be concentrated on smaller areas within the larger site, and fencing these areas, then shifting focus to new small areas over time, and moving the fence to accommodate the shift. Applying any of these methods may be most successful if managers field test techniques before applying them to the entire forest restoration site.

Literature Cited

Anderson, R.C. and A.J. Katz. 1993. Recovery of browse-sensitive species following release from white-tailed deer *Odocoileus virginianus* Zimmerman browsing pressure. Biological Conservation 63:203-208.

Ashby, W. 1997. Soil ripping and herbicides enhance tree and shrub restoration on stripmines. Restoration Ecology 5(2): 169-177.

Augustine, D.J. and L.E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. Conservation Biology 12(5): 995-1004.

Beringer, J., L.P. Hansen, R.A. Heinen, and N.F.Giessman. 1994. Use of dogs to reduce damage by deer to white pine plantation. Wildlife Society Bulletin 22(4): 627-632.

Borgmann, K.L., D.M. Waller, and T.P. Rooney. 1999. Does balsam fir (*Abies balsamea*) facilitate the recruitment of eastern hemlock (*Tsuga canadensis*)? American Midland Naturalist 141(2): 391-397.

Burt, W.H. and R.P. Grossenheider. 1980. A field guide to the mammals of North America and Mexico. The Peterson Field Guides Series, 3rd edition.

Coffey, M. and G. Johnston. 1997. A planning process for managing white-tailed deer in protected areas: Integrated pest management. Wildlife Society Bulletin 25(2): 433-439.

Cornell University. 2000. Extension publication: Reducing deer damage. www.dnr.cornell.edu/ext/chdp/reducingdamage3.htm (Accessed 15 November 2000).

Cornett, M. 2000. Minnesota Department of Natural Resources. Personal communication.

DelGiudice, G.D. and M.R. Riggs. 1996. Long-term research on the white-tailed deer/conifer thermal cover relationships: aligning expectations with reality. Transactions of the 61st North American Wildlife and Natural Resource Conference.

Garrott, R.A., P.J. White, and C.A. Vanderbilt White. 1993. Overabundance: an issue for conservation biologists? Conservation Biology 7(4): 946-949.

Gillette, L. 2000. Wildlife manager, Hennepin Parks, Minneapolis, MN, USA. Personal communication.

Harris, M.T., W.L. Palmer, and J.L. George. 1983. Preliminary screening of white-tailed deer repellents. Journal of Wildlife Management 47(2): 516-519.

Hiller, I. 1996. The white-tailed deer. Texas A&M University Press, College Station.

Johnson, E. 1997. Restoring upland hardwood forests using tree shelters. Restoration and Reclamation Review 2(6). Restoration Techniques-Forests. www.hort.agri.umn.edu/h5015/rrr.htm

Meffe, G. K. and C.R. Carroll. 1997. Principles of Conservation Biology, 2nd edition. Sunderland, MA: Sinauer Associates, Inc. pp.260-261.

Opperman, J. and A. Merenlender. 2000. Deer herbivory as an ecological constraint to restoration of degraded riparian corridors. Restoration Ecology 8(1): 41-47.

Palmer, W., R. Wingard, and J. George. 1983. Evaluation of white-tailed deer repellents. Wildlife Society Bulletin 11(2): 164-166.

Raycroft, M. 2000. White-tailed deer. Firefly Books, Ltd.

Ross, B., J. Bray, and W. Marshall. 1970. Effects of long-term deer exclusion on a *Pinus resinosa* forest in north-central Minnesota. Ecology 51: 1088-1093.

Shea, K.L. 2000. St. Olaf College, Northfield, MN, USA. Personal communication.

Stange, E.E. and K. Shea. 1998. Effects of deer browsing, fabric mats, and tree shelters *on Quercus rubra* seedlings. Restoration Ecology 6(1): 29-34.

Swihart, R., J. Pignatello, and M. Mattina. 1991. Adverse responses of white-tailed deer, *Odocoileus virginianus*, to predator urines. Journal of Chemical Ecology 17: 767-777.