Restoration of Damaged Stands: Dealing with the After Effects of Hemlock Woolly Adelgid

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Abstract

Eastern hemlock (*Tsuga canadensis* (L.) Carr.) is an evergreen conifer that is widely dispersed in the northeastern United States. Loss of the hemlock component in the eastern forest due to the introduced hemlock woolly adelgid (*Adelges tsugae*) will have long-term consequences for terrestrial and aquatic ecosystems. Some of the functional attributes of hemlock (vertical structure diversity, evergreen canopy, etc.) can be restored by planting alternative species such as eastern white pine and Norway spruce. Stand recovery plans include delineating hemlock stands, protecting some stands to provide a local seed source, developing salvage cutting priorities and standards, prioritizing stands to be replanted, and protecting new plantings from deer browse damage. Hemlock seedling survival and growth can be greatly increased by using browse protection.

Keywords:

Tsuga canadensis, browse control, reforestation.

Introduction

Eastern hemlock (*Tsuga canadensis* L. Carr.) is the most widely dispersed shade-tolerant conifer in the eastern United States (Godman and Lancaster 1990). Hemlock was present in nearly 19 million acres of timberland in the northeast region (Schmidt and McWilliams 1995). Hemlock is currently threatened in the eastern part of its range by the introduced hemlock woolly adelgid (*Adelges tsugae*). The economic value of hemlock (timber and pulp) is probably overshadowed by its importance in augmenting terrestrial habitat diversity, maintaining aquatic habitat integrity, and its esthetic appeal. However, as hemlock are killed by hemlock woolly adelgid, many hemlock stands will be replaced with deciduous species such as black birch (*Betula lenta*) and red maple (*Acer rubrum*) (Orwig and Foster 1998).

The deep, dense canopy of eastern hemlock increases vertical structure heterogeneity in forests, and more than 120 vertebrate species utilize mature stands (DeGraaf et al. 1992). Hemlock forests also provide thermal cover and forage for a variety of mammals including porcupines (*Erethizon dorsatum*) and white-tailed deer (*Odocoileus virginianus*), (Wydeven and Hay 1996; Reay et al.

1990). Nearly 90 species of birds can be found in hemlock forests (Lapin 1994). Several species are significantly associated with hemlock forests, including black-throated green warbler (*Dendroica virens*), Blackburnian warbler (*Dendroica fusca*), and red-breasted nuthatch (*Sitta canadensis*). Hemlock maintains aquatic habitat integrity by regulating stream flow and moderating water temperature. Increased nitrate leaching is likely following extensive hemlock mortality (Jenkins et al. 1999).

Loss of eastern hemlock from the eastern forest will lead to loss of habitat diversity. The objective of this paper is to address the steps necessary to reestablish an evergreen component in stands with extensive eastern hemlock mortality, thereby restoring habitat diversity. I am indebted to the participants of the “Hemlock Forest Ecosystem Best Management Practices Workshop” held in Hamden, Connecticut in November 1994 for the conceptual framework of restoring damaged hemlock stands. More extensive reviews and papers on eastern hemlock ecology can be found in Benzinger (1994), Lapin (1994), Mroz and Martin (1995), and McManus et al. (2000).

Remediation – Pre-Adelgid Control

Studies are currently underway to develop biological controls for hemlock woolly adelgid (McClure et al. 2000, Montgomery et al. 2000). Until there is an effective biological control of hemlock woolly adelgid, restoration will not be possible. Nevertheless, steps can be taken to minimize the impact that the loss of hemlock will have on ecosystem functions and aesthetic values, as well as speed recovery. This will take a multi-year commitment of personnel and funding and can be greatly facilitated by initiating planning prior to widespread hemlock mortality, thus avoiding crisis management.

The first step in developing a plan is to locate all stands with a significant hemlock component. In most cases this is easily done using existing aerial photography. Each stand can then be examined to determine locally relevant characteristics (age, diameters, volume, etc.) and degree of hemlock woolly adelgid infestation. This step will provide not only a baseline for monitoring the progression of adelgid infestation, but is essential for prioritizing the locations of salvage operations and reestablishment of an evergreen conifer component.

When possible, local populations with adaptations to regional differences in climate, soil, and photoperiod (Olson et al. 1959) should be protected from hemlock woolly adelgid. These stands also will provide a reminder of the importance and grandeur of hemlock forests. Chemical control will be required to maintain the health and vigor of these trees until an effective biological control is developed. Therefore, stands should be selected that have good accessibility to facilitate chemical control application. Good accessibility also will aid future seed collection. Selection criteria also could include healthy trees with medium-to-large crowns (not overstocked), trees with good stem form, and stands growing on high-quality sites.

Development of salvage cutting priorities and standards will facilitate objective management decisions and allocation of limited resources. Salvage cutting in hemlock stands, especially before complete mortality, has sparked public controversy in Connecticut. Objective standards that have included public input would assist in allaying the concern over cutting 'old-growth forests.' Criteria for determining salvage cutting priorities should include public safety, water quality, aesthetic (visual impact), wildfire potential, merchantability, and rate of hemlock decline.

Salvage cutting standards should strictly adhere to Best Management Practices as they pertain to insuring maintenance of water quality. Slash standards will vary depending on proximity to streams, public viewpoints, and whether or not the area will be replanted. Although high slash may protect regeneration from browse damage, low slash is preferable in areas with high public visitation and where new conifers will be planted. Salvage cutting standards also should include a number of residual snags.

Recovery of some of the ecological or esthetic attributes associated with hemlock forests is possible by planting alternative evergreen species. Because funding is limited, only a small fraction of the stands where hemlock is lost can be replanted. Therefore, a protocol should be developed to prioritize the order in which remediation efforts are accomplished. Criteria can include factors such as water quality (riparian buffer integrity), wildlife habitat, aesthetic impact, accessibility, and existing regeneration.

Ideally, selection of replacement species also will be made during the planning phase. Unfortunately, there is no native conifer species that has the unique attributes (evergreen, shade tolerant, soft foliage texture) of eastern hemlock. Therefore, forest managers will have to select a species that best achieves management objectives (e.g., stream shading). Selection criteria should include the importance of using native species, growth rate, reaction to competition, resistance to browse damage, site limitations, and availability.

Do not replace hemlocks with single-species plantations. The unfortunate reality is that other exotic insects and diseases will probably be introduced. Replacing eastern hemlock with a monoculture may well create a similar problem for future resource managers. Potential native species include eastern white pine (*Pinus strobus*), eastern red cedar (*Juniperus virginiana*), northern white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), Fraser fir (*Abies fraseri*), Atlantic white cedar (*Chamaecyparis thyoides*), and white spruce (*Picea glauca*). Non-native species that may be used include Norway spruce (*Picea abies*), Colorado spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii*), sawara (*Chamaecyparis pisifera*), cedar of Lebanon (*Cedrus libani*), western hemlock (*Tsuga heterophylla*), Japanese hemlock (*Tsuga diversifolia*), and English yew (*Taxus baccata*).

Planting operations require careful orchestration of personnel, planting stock, planting equipment, and browse protection (if needed). Seedlings are perishable and should be planted as soon as possible after they are delivered from the nursery. Unless experienced planting crews are used, provide a training session for personnel. Check planting sites for accessibility and amount of slash. If using volunteers to assist in planting, then it may be necessary to obtain planting bars, shovels, and planting bags.

Reestablishing an evergreen component in forests that had been dominated by eastern hemlock will be especially difficult in areas with large deer herds. Eastern hemlock and other conifers are preferred browse species (Anderson 1984). Personal observation has shown that deer prefer browsing on nursery seedlings, perhaps because they have high nutrient levels. Planted seedlings should be immediately protected from browse damage. A more detailed description of browse protection devices can be found later in this paper.

Lastly, a plan to monitor and control hardwood competition should to developed. Conifer seedlings often are overtopped by hardwood regeneration. These competitors can limit the amount of available light (Salonius and Beaton 1997). Height growth and survival of overtopped seedlings can be greatly reduced. A machete or brush hook can be used to remove larger hardwoods until the conifer seedlings have become well established with vigorous crowns.

Remediation – Post Adelgid Control

After effective biological control methods of controlling hemlock woolly adelgid and scale have been developed, it will possible to reintroduce hemlock into the landscape. Seed could be collected from trees protected from hemlock woolly adelgid to produce seedlings adapted to regional differences in climate, soil, and day length. Expertise gained growing other conifer species while biological control were developed can then be applied to repatriate eastern hemlock. This experience will be especially crucial in areas where browse damage can be anticipated.

Controlling Browse Damage

A study was began in 1990 to investigate the efficacy of various protection devices to increase height growth and survival of eastern hemlock by reducing deer browse damage. Planting sites were established in northern Connecticut at Mohawk Mountain (41^{o}48’N, 73^{o}18’W). Hunting was prohibited on the forest and large deer herds limit the ability of conifer species to regenerate. Deer densities averaged 18 per km^2 (47 per mile^2) (Ward and Stephens 1995). Planting sites were located in recently clearcut red pine plantations.

Eastern hemlock seedlings were planted at three sites within the forest in spring 1990. Seedling characteristics were measured before planting. Seedlings were stratified by root collar diameter (RCD) before assignment to treatments. There were 10 to 30 seedlings for each treatment at each planting site. Tree height (to the nearest cm), browse damage, and any distortions of the terminal leader were measured at the end of each growing season for seven years. Initial seedling size was 19 cm (7.7 inches). All plots were cleaned with chainsaw and machete prior to planting and 2 years after planting. More detailed descriptions of the study design and measurements can be found in Ward (1997) and Ward et al. (2000).

The browse protection treatments included: tree shelters (solid tubes), plastic mesh sleeves supported by a bamboo stake, a Reemay (spunbonded polypropylene fabric) sleeve supported by a bamboo stake, and unprotected controls. The initial study had three tree shelter styles and two styles of both mesh sleeves and Reemay sleeves. Preliminary analysis found no significant difference in height and mortality among styles for each treatment. Therefore, data for the styles within each treatment were pooled. Tukey's HSD test (SYSTAT 1992) was used to test differences in 7th year height among treatments and among initial seedling size classes. Chi-square statistics were used to determine whether mortality differed among treatments. Differences were considered significant at $p \leq 0.05$.

Height of eastern hemlock seedlings after seven growing season differed significantly among browse protection methods ($F = 7.12$, $df = 3$, $p < 0.001$). Unprotected seedlings were half the height of seedlings protected by mesh sleeves and significantly smaller than seedlings protected by mesh sleeves and tree shelters (Figure 1). A study in Wisconsin also found hemlock survival and growth were increased when protected from browse damage (Peczynski and Jones 1996). Seedlings protected by Reemay sleeves also were significantly smaller than seedlings protected by mesh sleeves. This is similar to results found for other species (Kittredge et al. 1992; Burger et al. 1992).

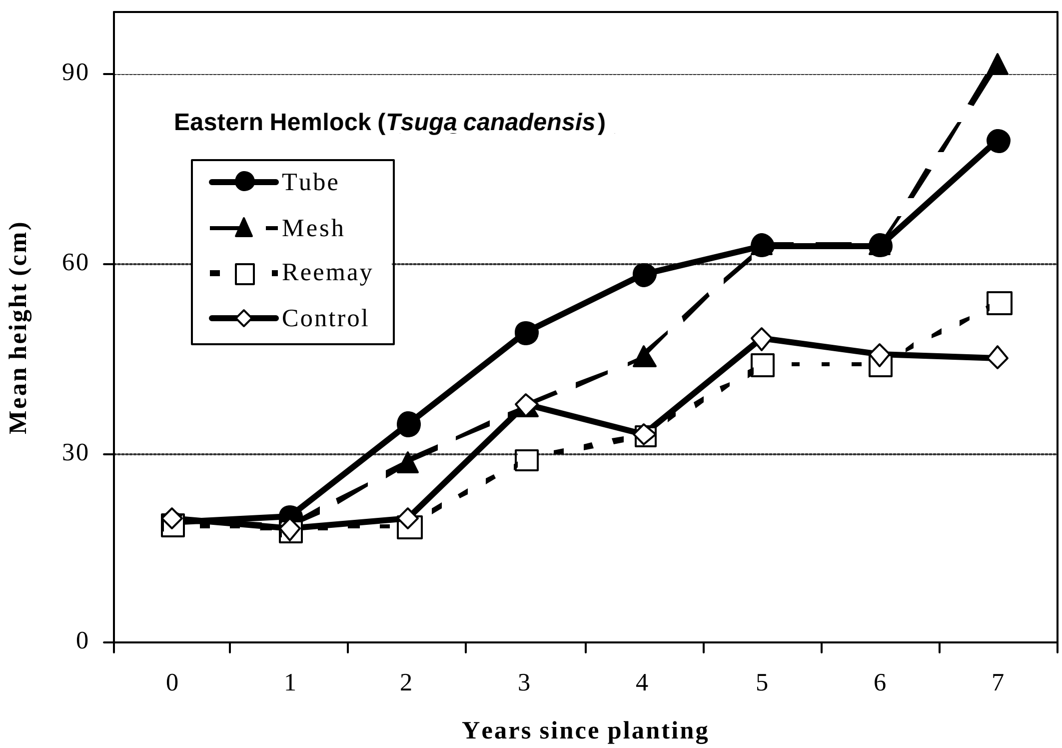

Figure 1. Height (cm) of eastern hemlock seedlings at end of growing season by browse protection device.

Some of the increased height growth of seedlings protected by tree shelters and plastic mesh could be attributed to lower levels of browse damage. Browse of seedlings within tree shelters was caused by either mice gnawing through tubes and then on seedlings or deer browsing on seedlings that had grown too large to be protected. Height growth of seedlings protected by Reemay sleeves may have been limited because the fabric gradually frays. Then sleeve interior often became a dense fiber web that snagged and limited expansion of the terminal leader.

Survival of eastern hemlock seedlings also differed among browse protection methods ($c^2 = 16.2$, d.f. = 3, $p \leq 0.001$). Only one-third of unprotected seedlings survived the first seven years (Figure 2). Survival for both the mesh and Reemay sleeves averaged 50% through seven years, and survival for tree shelters averaged more than 70%. It is worth noting that most mortality occurred by the end of the fourth growing season.

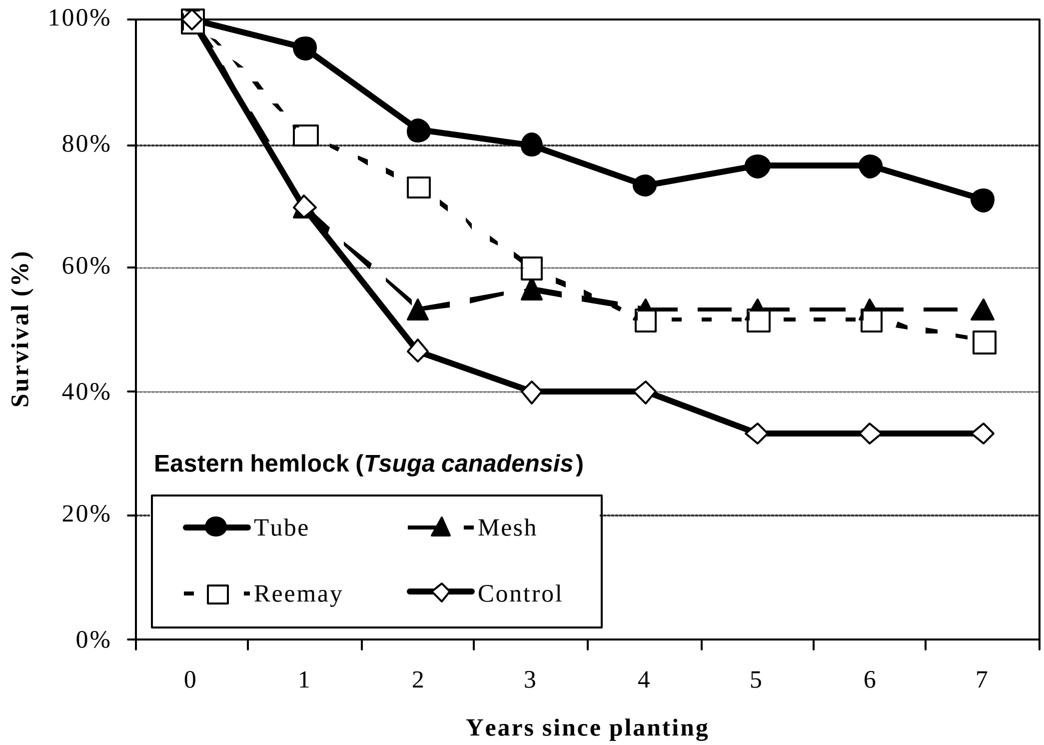

Figure 2. Survival (percent) of eastern hemlock seedlings at end of growing season by browse protection device.

In a study began in 1997, we examined the feasibility of using a system of rigid mesh tubes and bud caps. Eastern white pine (*Pinus strobus*) seedlings were planted in an open meadow that had an estimated deer density of 23 per km^2 (60 per $mile^2$). Eighty seedlings were not protected, and eight seedlings were protected with a combination of rigid mesh tubes (Vexlar) and bud caps. The average height of protected seedlings was nearly 60 cm after four years, compared with 11 cm for unprotected seedlings. Survival of unprotected seedlings was only 4% compared with 49% for protected seedlings. This system has great promise for conifers with a rigid central leader (e.g., *Pinus* and *Picea*).

Artificial regeneration of trees in areas with high deer populations is often a waste of material and labor without browse protection. This study suggests that eastern hemlock seedlings can benefit from using browse protection devices, especially when early rapid height growth is crucial. The decision to use browse protection, and the type of browse protection used, should only be made after a careful analysis of the costs. In some circumstances, it may be more cost effective to use larger seedlings. However, the cost effectiveness of using larger conifer seedlings in the east has not been fully elucidated.

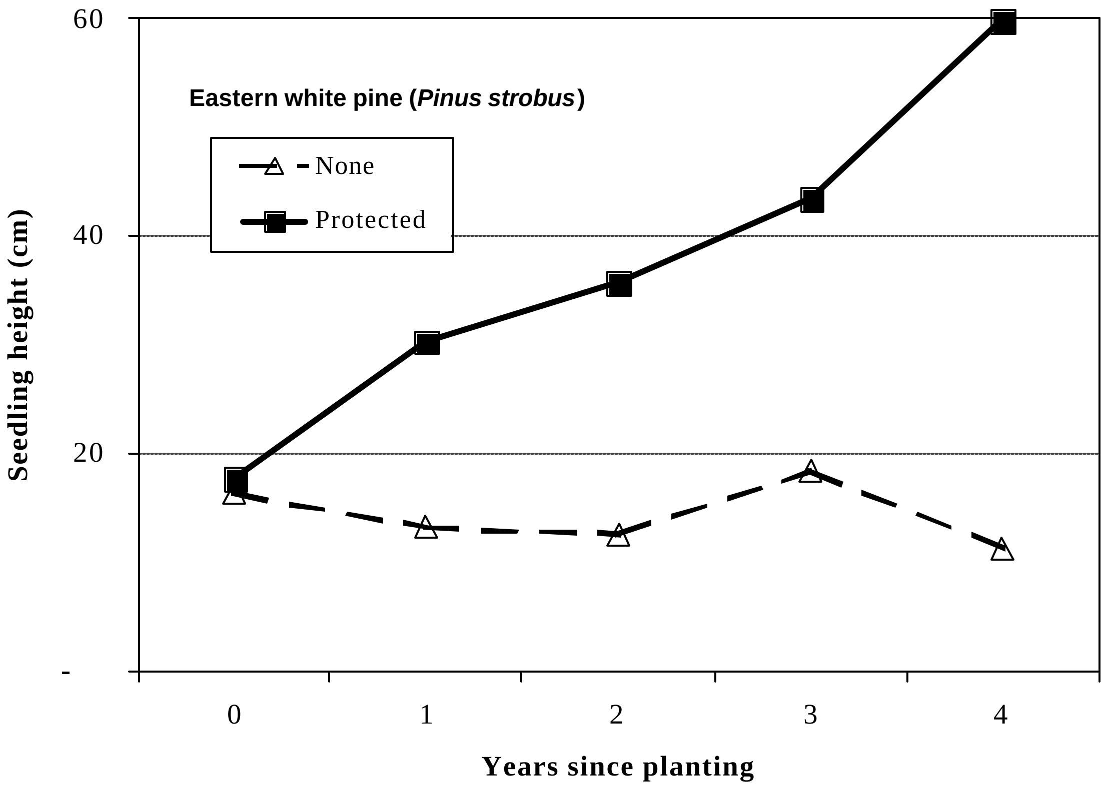

Figure 3. Height of eastern white pine seedlings at end of growing season by browse protection method (Non-no protection, Protected - rigid mesh tubes and bud caps).

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