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# Natural and Artificial Regeneration as it Relates to the Establishment and Maintenance of Riparian Forest Buffers in the Northeastern U.S.: A Literature Review





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## **SUMMARY**

This document summarizes information currently available on establishing and maintaining naturally and artificially regenerated riparian forest buffers in the Northeastern United States. It includes information on site preparation alternatives and planting processes. It summarizes the results of empirical research, practical applications, and discusses future research needs. A bibliography is included.

## **INTRODUCTION**

The goal of this document is to cite the available literature on establishing riparian forest buffers using natural and artificial regeneration. Specifically, this paper presents the existing information on the use of natural regeneration either alone or in conjunction with tree plantings, or tree plantings (artificial regeneration) alone that meet the functions of a riparian forest buffer. In addition, literature was reviewed on the effectiveness of different types of site preparation and planting maintenance on establishing forest buffers. It should be noted that throughout this review it is presumed that planting in the spring is the optimal time of the year with site preparation occurring in the previous fall. In some areas of the northeast, this probably will vary. Technical experts in each state should have more detailed information on the timing of preparation and planting.

A formal request was made through the Partnership Management Team (PMT) Research and Technology Needs Request Process to compare naturally regenerated riparian buffer survival and growth versus planted buffers. In addition, it was requested that several methods of site preparation/planting be evaluated for cost

(costs are not included in this report) and effectiveness. It was felt that this would help the field staff in planning riparian buffers and at the same time show NRCS successes.

## **FINDINGS**

In general, success in establishing a riparian forest buffer depends largely on site conditions. Previous and current land use, soil type, soil drainage, hydrologic and geomorphological processes, existing native plant community and ecosystem classification, wildlife diversity, invasive plants, wildlife pests, and human activity problems, must be determined prior to deciding on the methods of establishment and maintenance. Establishing a history of succession is very important and in urban riparian ecosystems determining the appropriate natural disturbance regime to mimic and/or reinstate is critical (Binelli 2000). Other information on the site that is useful includes cultural resource concerns, legal restrictions, political, historical and social significance, and environmental vandalism problems (Coder 2000). The available literature emphasizes that all these factors must be evaluated before attempting any restoration efforts. As stated by E. Verry in "Riparian Management in Forests of the Continental Eastern United States", we must take time to develop local ecosystem classifications and start with a landscape perspective when managing riparian areas. For example, depth to water table greatly affects maximum vegetation height, and in the context of the topography of riparian areas, gives rise to edge patterns that increase plant and animal diversity. In terms of planting a site, this includes considering certain plants for areas that are below bankfull elevation, such as willows and alder. This is especially important where

the water table adjacent to the channel is high enough to exclude trees. Plant communities play a significant role in determining the condition, vulnerability, and potential for (or lack of) restoration of the stream corridor (USDA 1998). According to a study conducted by the National Council for Air and Stream Improvement (NCASI) in 2000, non-vegetative factors such as side slope gradient, flood duration, flood-prone width, and the degree to which streams are constrained, appear to influence the broad range of riparian functions as much as vegetative factors. M. Duryea explains in "Forest Regeneration Methods: Natural Regeneration, Direct Seeding and Planting", successful survival is more likely with planting compared to natural regeneration or direct seeding. Other studies have found that the use of planting and natural regeneration together is highly successful as well (Pannill 2001 and Okay and Forman 2001).



#### **ARTIFICIAL REGENERATION**

Artificial regeneration is defined as species reproduction obtained by planting young trees or applying seed to the land. Numerous publications are available that give general guidelines on artificial regeneration including site preparation, planting, and maintenance. Many of these are available from the Internet. Web

addresses are included in the Bibliography when available.

The following is a listing of some of the more riparian buffer-oriented planting guides:

- *Riparian Buffers for the Connecticut River Watershed, Fact Sheet No. 8 - Planting Riparian Buffers in the Connecticut River Watershed* -- developed by the Connecticut River Joint Commissions of NH & VT.
- *Stewards of our Streams, Multi-Species Buffer Strip Design, Establishment and Maintenance* -- developed by Iowa State University Extension.
- *Forestry Report, Establishing Riparian Buffers, and Conservation Tree Planting Schedule* -- developed by the Kansas State University Cooperative Extension Service.
- *Economics of Riparian Buffers* -- developed by the University of Maryland.
- *Riparian Forest Buffer Design, Establishment and Maintenance* -- developed by the University of Maryland Cooperative Extension.
- *Riparian Forest Buffer Handbook* -- developed by the USDA Forest Service.
- *Riparian Forest Buffer, Code 391, Conservation Practice Job Sheet* -- developed by the USDA Natural Resources Conservation Service. 2003.
- *Riparian Forest Buffer Standard, Code 391, National Conservation Practice Standards* -- developed by the USDA Natural Resources Conservation Service. 2000.
- *Understanding the Science Behind Riparian Forest Buffers: Planning, Establishment, and Maintenance* -- developed by the Virginia Cooperative Extension.

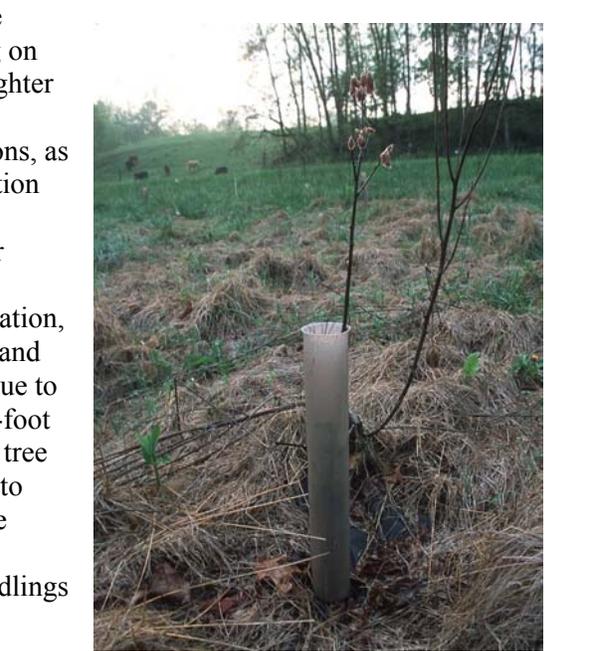
- *Plant It Right: Restoration Planting Techniques* -- developed by the Washington State University Cooperative Extension.

All of the above publications have numerous methods and techniques in common.

The following is a listing of the major points to consider when planting and maintaining a riparian forest buffer:

<i>When and What to Plant</i>	<ul style="list-style-type: none"> <li>• Consider planting a variety of species in successive years instead of all in one year. This will increase the age diversity in the buffer and create multi-age ecosystems (forests) in several stages of ecological succession. These plantings should be in combinations that mimic nearby ecosystems (Binelli 2000). Plant understory species later because they usually do not tolerate full sun (Connecticut River Joint Commissions of NH &amp; VT 2000). Plant early successional species for fast growth and interplant climax species for long-term diversity and buffer function.</li> </ul>
<i>Where and How Much to Plant</i>	<ul style="list-style-type: none"> <li>• Trees should be planted at a stocking density of 400 trees per acre. This results in a minimum survival rate of 50 percent or 200 stems per acre at establishment and crown closure at a height of 15 feet (Sweeney et. al. 2002 and Pannill 2001). Plant on a 3-meter (10-foot) spacing (Sweeney 1993).</li> <li>• Arrange plantings to create a gradual edge rather than an abrupt one, for a more natural appearance and for blow down protection (Connecticut River Joint Commissions of NH &amp; VT 2000).</li> <li>• If production of biomass for energy is a goal in Zone II (defined as the upland area perpendicular to the stream, 15 feet from the top of the bank, and at a minimum 20 feet in width), use a closer spacing between and within rows. For timber production, use wider spacing between and within rows. Space plants far enough apart so that the area can be mowed or herbicided along plant rows the first 3 years (Schultz et. al. 1991).</li> </ul> <div data-bbox="797 1087 1437 1543" style="text-align: right;">  <p><i>Riparian buffer planting using wider spacing.</i></p> </div>
<i>Weed Control - General</i>	<ul style="list-style-type: none"> <li>• There are two broad categories of weed control in tree planting projects. The first is the control of seeds from woody vegetation, annual and perennial grasses, and broadleaf weed species. The second is the control of existing weed species plants (DuPlissis 1998).</li> </ul>

<p><i>Site Preparation</i></p>	<ul style="list-style-type: none"> <li>• Prepare the site by herbiciding, mowing, bush hogging, or prescribed burning. Fall site preparation is essential if planting into an established grass sod, such as a hay meadow or pasture. If possible, disking the fall before allows for freezing and thawing over winter, which breaks up and settles clods. This exposes the roots and effectively kills the grass. For compacted soils that may restrict tree root growth, use a subsoil ripper or shank plow in the planting row before planting (Barden 2001). Old fields, pastures, and sites with grass or sod usually require some type of scalping (form of furrowing) (Alm, et al. 1994). An alternate site preparation method involves establishing a cover crop of non-sod-forming grasses, which precludes noxious weeds and dies back in summer (Pannill et al. 2001). Fall preparation should include eliminating competing perennial vegetation in 3 to 4 feet-wide strips or circles where the plants will be planted (Schultz et. al. 1991). Weed control should be started before the trees are planted. Pre-emergence herbicides can be incorporated into the soil during the spring tillage before planting. Post-emergence herbicides control weeds in the fall before planting and after the plantings are established (DuPlissis 1998).</li> </ul>
<p><i>Invasive Plant Control</i></p>	<ul style="list-style-type: none"> <li>• If invasive weeds are a problem, it is important to control them before the vegetation is planted (Palone and Todd 1997). Where the problem is severe, this can require as much as a year of successive treatments. Invasive weeds of particular concern in riparian areas are phragmites (common reed), oriental bittersweet, Japanese honeysuckle, kudzu, porcelain berry, mile-a-minute vine, trumpet creeper vine, Japanese bamboo (knotweed), privet, multiflora rose, tree-of-heaven, and Norway maple. Invasive weeds can be controlled by either mechanical or chemical means. Examples of mechanical control are mowing</li> </ul> <div data-bbox="597 1136 1203 1524" data-label="Image"> </div> <p><b><i>Japanese barberry understory. (Source unknown)</i></b></p> <ul style="list-style-type: none"> <li>multiple times over the growing season to exhaust root systems, ripping them out with a tractor, or girdling the plants. Only use herbicides recommended for use in riparian areas. Weeding and mowing will be necessary the first three years or until the trees are established (Klapproth and Johnson 2001). Manage invasive species that crowd and compete with seedlings (Okay 2001). This includes keeping disturbance of the site down to a minimum. Disturbance</li> </ul>

<p><i>Invasive Plant Control (continued)</i></p>	<p>does not just imply vegetation clearing or soil disturbance, it includes altered drainage patterns, fire suppression, waste dumps, and stormwater runoff filled with fertilizers or pesticides (Dozier 2000).</p>	
<p><i>Tree Planting Recommendations</i></p>	<ul style="list-style-type: none"> <li>• Use 3 to 5-foot tree shelters, depending on the species. Use lighter colored shelters in partial light situations, as in natural regeneration shelterwood sites (Schuler and Miller 1995). The shelters reduce animal predation, weed competition, and reduce water loss due to wind. The use of 4-foot tall plastic tubes as tree shelters was found to sharply increase the growth rate and survivorship of seedlings (Sweeney 1993).</li> </ul>	
		<ul style="list-style-type: none"> <li>• Use herbicides around the base of tree shelters or tree mats to eliminate vegetative competition (Okay 2001). Weed control is most important during the first 3 to 5 years after seedlings are planted (DuPlissis 1998). Continue weed control until woody plants occupy the area. If you mow, mow once or twice a growing season. Late fall mowing removes rodent habitat that helps minimize plant damage during the winter (Schultz et.al. 1991). Weed barrier fabric applied at the time of planting is effective, but may not be good in flood-prone sites due to disturbance or sedimentation (Barden 2001). Another weed control measure proposed is covering bare soil where trees and shrubs are to be planted with less-competitive cool season grasses to hold the soil and discourage weeds until woody plants become established (Connecticut River Joint Commissions of NH &amp; VT 2000).</li> </ul>

***Close-up of Japanese knotweed (bamboo). (Source unknown)***

***Close-up of tree shelter tube.***

<p><i>Tree Planting Recommendations (continued)</i></p>	<ul style="list-style-type: none"> <li>• Be sure there is a good seal around the bottom of the shelter (Okay 2001). This will prevent mouse damage.</li> <li>• Handle seedlings with care from time of digging to replanting (Okay 2001). One to two-year old bare-rooted seedlings of most trees and shrub species, or rooted or unrooted cuttings, should be used. Quality hardwood seedlings should have a minimum of four to five large lateral roots. Consider ordering 10 to 15 percent more trees and shrubs than what you think you will need for the job (Schultz et. al. 1991).</li> </ul> 
<p><i>Species to Plant</i></p>	<ul style="list-style-type: none"> <li>• Select native, non-invasive species. Existing riparian vegetation can be a good indicator of which species will grow well on the site (Klapproth and Johnson 2001). If available, use appropriate Ecological Site Descriptions (ESDs) (NRCS) or other historical plant community descriptions developed by federal, state, or local conservation agencies or organizations to develop a list of plants suitable for the site. Native deciduous trees are recommended for planting in Zones 1 and 2 to maximize habitat value for fish and wildlife and water quality benefits (Schultz and others 1995). Trees planted on the stream bank should be selected for their ability to withstand frequent disturbance and flooded conditions. These trees must also provide bank stability, a dense canopy for shade, and food for aquatic organisms. Native species that are fast-growing and easily established are good choices here, including river birch, black willow, red maple, eastern cottonwood, green ash, and sycamore (Hupp 1992 and Palone and Todd 1997). The following are some typical herbaceous plants that occurred more than 70 percent of the time in riparian forest buffers in Maine (percent occurrence indicated after the common name) (Whitman and Hagan 2000): Blue-bead Lily (100), Bunchberry (100), Starflower (100), Wild Sarsasperilla (100), Mountain Woodfern (100), Evergreen Woodfern (100),</li> </ul>  <p><b><i>Close-up of bunchberry and other forest flora.</i></b></p>

<p><i>Species to Plant (continued)</i></p>	<p>Canada Mayflower (100), Gold Thread (100), Whorled Aster (80), Wood Sorrel (90), Long Beech Fern (70), Painted Trillium (90), Rose Twisted Stalk (70), and Large-leaved Goldenrod (80). Ask about the source of any plant material before purchasing it to make sure it is acclimated to your area.</p>
	<ul style="list-style-type: none"> <li>• Non-native plants may attract deer. Use native plants known to be less palatable to them. Plants of low value to deer include alder, spruce, hemlock, tamarack, beech, hornbeam, and viburnum. Dogwoods, willows, ash, and yellow birch will endure heavy browsing and sprout again. Mixing shade-tolerant canopy trees among fast growing trees will reduce deer browsing on future dominant species. Plants of low value to beaver include spruce, white cedar, hemlock, tamarack, beech, red maple, and paper birch. Use a dense barrier of shrubs to discourage Canada geese and use raspberries or blackberries to discourage trespassing humans. (Connecticut River Joint Commissions of NH &amp; VT 2000).</li> </ul>
	<ul style="list-style-type: none"> <li>• Select some species that are considered secondary successional species (Okay 2001). Use a mix of successional and climax species (Sweeney 1993). Where conifers tend to follow riparian hardwoods, generally north of Route 2 in the northern Connecticut River Valley, plant conifers among blocks of pioneer species to speed the transition (Connecticut River Joint Commissions of NH &amp; VT 2000). When planting into an existing, naturally regenerated buffer, planted species should include native species, such as oak, which are not well represented as volunteer seedlings (Pannill 2001).</li> </ul> <div data-bbox="605 808 1133 1203" style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p><i>Pioneer white birch planted with white pine.</i></p> </div> </div>
<p><i>Buffer Maintenance</i></p>	<ul style="list-style-type: none"> <li>• Prevent buffer alterations, including tree removal, conversion to lawn (or other land use change), trampling and foot trails, filling, encroachment (reduction in size), dumping of yard wastes, and erosion by stormwater runoff. Narrow buffers (50 feet or less) on residential lots are extremely susceptible to disturbances (Cooke and Castelle et. al. 1992). If access to the stream is necessary, provide a definite path to reduce unlimited access through the buffer.</li> <li>• For a continuous annual harvest of Zone II after the first 8 years, remove 1/8 to 1/12 of the total tree zone each year and make sure the harvested trees regrow or are replanted (Schultz et. al. 1991).</li> <li>• Make sure the landowner(s) understands the purpose of the buffer and why it needs to be maintained and/or protected (Cooke 1992).</li> <li>• Monitor the project site over the first 1 – 2 years after planting so that dead or damaged plants can be replaced as necessary. Also periodic monitoring of sites, every 3 to 5 years should be conducted to ensure the buffer, once established, is not lost (Matter and Mannan 1988).</li> </ul>

Success in establishing a forest riparian buffer is measured on whether or not an adequate number of trees have been established to create forest-like conditions on the site within a reasonable period of time. An important measurement of success is the survival and growth of planted trees (are the trees and shrubs being planted successfully). Related issues are the role of natural regeneration in supplanting or augmenting planted stock, and the relative benefits of using tree shelters and balled and burlapped or containerized saplings. Also, the species planted may have an impact on the economic and ecological value of the buffer, and the future management expectations. It is also valuable to know which species tend to be successful and which should no longer be planted in certain situations, if at all (Pannill et.al.2001). It is estimated that it takes 7 to 10 years for a buffer to become established by planting seedlings (Sweeney 1993). Data also suggests that in the mid-Atlantic region, full canopy cover could be achieved in 15 years or less by planting the streamside areas at a density of 400 trees per acre. The planted area would then be managed for an average of 15 feet of growth and approximately 50 percent survivorship by using herbicides and tree shelters (Sweeney, et. al. 2002). In Maryland, research suggests that a stocking rate of 200 trees per acre should achieve crown closure in about 10 years, with the preferred survival rate of 65 percent of the original planting density (Pannill 2001).

In urban areas the challenge is to determine the appropriate natural disturbance regime to mimic and/or reinstate it. This is because in urban areas there is little natural succession. A site inventory should be conducted to determine the potential of the site (Binelli et al. 2000). In urban settings, the soil attributes also need to be restored to

successfully restore the ecosystem structure and functions (Coder, 2000).

Many of the studies include timelines for the restoration of buffer functions in conjunction with the buffer restoration. Concurrent with canopy cover closure, 15 to 20 years may be required before buffers begin to control nitrate loads (Klapproth and Johnson 1998). In Virginia, wildlife biologists observed significant use of streamside areas by birds within 5 to 9 years after they had been cleared and allowed to revegetate naturally (Ferguson et al 1975). Stream cooling and inputs of large woody debris will occur slowly, over many years (Klapproth and Johnson 1998).

Planting considerations include initial costs that may be higher than for natural regeneration. Another consideration is if the planting site is inaccessible to planting machines or crews. Distortions of the root system such as "L" or "J" shaped roots may result from improper planting. Close attention to seedling care and handling is also critical because poor survival and growth may result if seedlings are mistreated (Duryea 2000).

## **NATURAL REGENERATION**

Natural regeneration is defined as species reproduction obtained by natural seeding or from sprouts. The literature available concerning natural regeneration is limited, especially for restoration of riparian areas. What is known is that naturally vegetated riparian areas are among the most productive and diverse plant communities (Klapproth 2001). This vegetation is adapted to wide fluctuations in water levels and regular disturbances. One of the most recent studies to be completed was in Maryland by the Department of Natural Resources - Forest Service in April of 2001. They found that a large percentage of their planted survey sites contained natural



***Naturally regenerated riparian buffer.***

regeneration, and that regeneration reflected the native plant communities at those sites. They found higher stocking levels and survival rates on sites with natural regeneration.

On the other hand, a study being conducted by Sweeney in Pennsylvania concluded that natural regeneration was not a viable option for restoring forest buffers there. This is because of high local incidence of herbivores and exotic, invasive species competitors, an insufficient quantity or poor

diversity of local desirable seed source, and a need to quickly restore habitat and water quality of the stream.

In Maryland, sites that contained an abundance of natural regeneration also were sites that had very little maintenance and showed a greater diversity of species. Regeneration was found more in clumps than equally dispersed across the whole buffer survey site. Of the trees and shrubs found as natural regeneration in a Maryland study by Pannill, the top ten species found were: sweetgum, boxelder, hawthorn, black cherry, green ash, ailanthus, red maple, black walnut, black locust, and loblolly pine.

In a Virginia study conducted by J. G. Okay, a considerable number of the sites with natural regeneration were populated with



***Pioneer white birch with hemlock regeneration.***

short-lived pioneer species. Common Riparian Corridor Pioneer Species according to Verry et al. in 2000 are: *Acer rubrum*, *Betula nigra*, *Carya* sp., *Fraxinus pennsylvanica*, *Liriodendron tulipifera*, *Populus deltoids*, *Nyssa sylvatica*, *Platanus occidentalis*, *Quercus alba*, *Salix nigra*, *Quercus bicolor*, *Taxodium distichum*, and *Ulmus* sp.

In C. J. Barden's publication, "Establishing Riparian Buffers", natural regeneration is the least expensive, least certain method. It requires a nearby seed source of mature trees. The resulting stand usually is dominated by fast-growing species, such as cottonwood, elm, silver maple, boxelder, and willow, all of which have wind-borne seeds. In many cases, pastureland can be naturally regenerated by fencing off the area for several years. The stand resulting from fencing the riparian area usually will be dominated by bird-dispersed or larger-seeded species that were not palatable to grazing livestock, typically honeylocust, Osage orange (hedge), hackberry, and eastern redcedar. Some sites have a good number of oak and ash seedlings already present that simply need protection from the trampling and grazing to grow well (Barden 2001). Suppression of competing pasture plants may be necessary for native plant establishment (Reichard 1984).

The Connecticut River Joint Commission of NH & VT suggests that natural regeneration can be accomplished by simply ignoring the riverbank and creating a no-mow zone. Over time plants can be added and non-native or unhealthy ones can be removed. This is the easiest and least costly way to establish a buffer, but you'll have to wait awhile and if your bank is poorly vegetated, it may erode in the meantime.

Using natural regeneration to revegetate channelized streams (those with stabilization structures) can be unpredictable and depends on a number of little-understood variables (Goldner 1984). These variables include channel slope lining (concrete or rip rap), availability of upstream seed sources, soil temperature and moisture, stream flow regime and velocities, steepness of side slopes, fertility and compactness of fill material, and intensity of vegetation and

sediment removal in the channel to maintain the constructed flow capacity.

Studies by Pannill et al., revealed the importance of natural regeneration in buffer creation and restoration. Natural regeneration has limitations such as invasive exotic species and very patchy seedling density, but it can offer inexpensive regeneration with native seed sources, desirable for wildlife and biodiversity. Considerations for naturally regenerating a buffer or augmenting a planted buffer include: minimizing noxious or invasive weeds, minimizing poor species diversity, and identifying sites where natural regeneration will not achieve the desired results.

Research by Binelli in 2000 concluded that natural areas in urban settings have much lower maintenance requirements when compared to traditional landscaping, but careful planning and monitoring are essential for success. In some urban landscapes, seed sources are sparse and deer browse has taken its toll on natural regeneration. This is similar to results in a Pennsylvania study by B. Sweeney (Sweeney, 2002).

In a study conducted in northwestern Pennsylvania on soil seed banks it was found that only a subset of the ground-layer species that occur in Allegheny Plateau riparian forests relies on the seed bank as a mechanism for population regeneration and maintenance. There was low overall similarity between species composition of the soil seed bank (13 species) and the existing vegetation (25 species) in the riparian forest (Hanlon, et.al. 1998).

## **DIFFICULTIES WITH REGENERATION**

Problems common to both types of buffer restoration methods include plant to plant



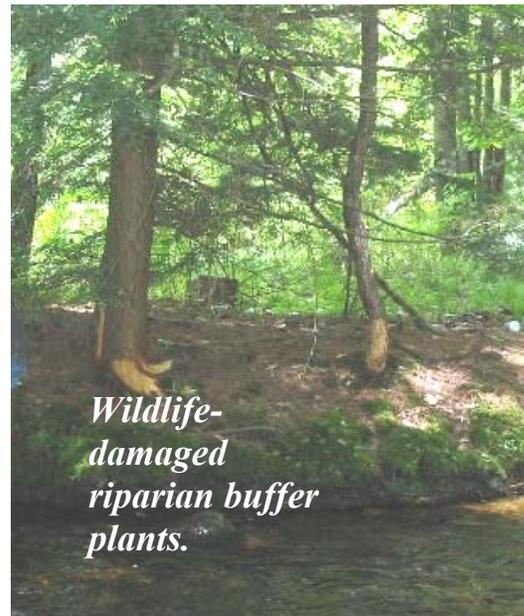
***Weed problems in riparian buffer planting.***

competition and herbivore damage. In order to promote natural regeneration, a less vigorous weed control program was needed to allow native seed to grow and survive. Mowing, an effective weed control measure for planted buffers, is detrimental to natural regeneration of desirable buffer species (Pannill et al. 2001). Spot treatment using herbicides was a better choice for weed control and may be used with more success than mowing in areas that had natural regeneration or random planting patterns.

In a study conducted by B. Sweeney in 1993 on White Clay Creek, weed control (twice annual mowing or careful application of herbicides) was the major factor influencing the survival rates of planted seedlings. After 11 years, 73 percent of seedlings survived where weed control had been practiced, as compared to 7 percent where it had not. Most of the mortality occurred in the first 3 years after planting.

Research by Schuler and Miller in 1995, shows that tree shelters promote a period of

rapid height growth by Northern red oak seedlings while protecting the seedling from injury from animals. Both planted and naturally occurring seedlings in forest clearings or sunny fields can use shelters with similar success resulting in increased height growth and survivorship. Both natural and planted seedlings that received some form of weed control in conjunction with a shelter averaged more than 10 feet tall -- almost 2 feet taller than



seedlings with a shelter alone. Survival of these seedlings was much higher also. They also recommended that sheltering should take place before spring leaf out. They observed that sheltering a natural seedling eliminates the cost to plant a seedling and ensures seed-source compatibility with the site. Because the use of tree shelters represents a significant financial investment, judicious use of this technique was warranted. There is the possibility of reusing the shelters, which can reduce the cost of using them. So, it may be more cost-effective to utilize more resources on fewer seedlings to increase survival probabilities and improve competitive position of individual seedlings and saplings.

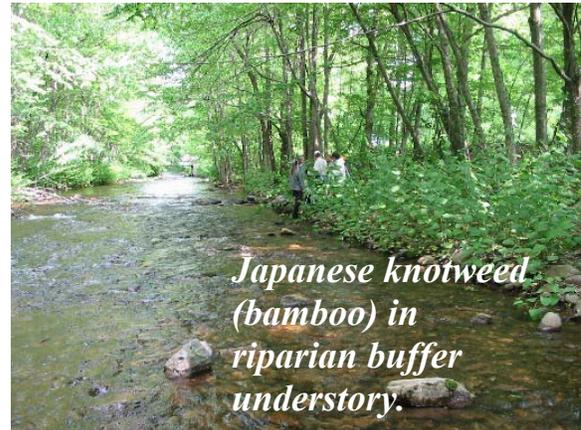
It is important to note that a study conducted by W. Sharpe et al. in 1999 shows that some types of shelters might inhibit growth, harbor pests, and increase diseases. This is especially true if using dark-colored shelters in partial light situations, as in one study conducted by Schuler and Miller where it caused 100 percent mortality. Pannill et al. observed distinctly greater survival of trees protected by tree shelters. According to their study results, use of shelters may be particularly justified for seedlings planted on urban/community sites or in sites with high density of herbivores.



In the Virginia Cooperative Extension publication “Understanding the Science Behind Riparian Forest Buffers, Planning, Establishment, and Maintenance”, exotic, invasive species are of particular concern in riparian areas. This bulletin suggests that a timber stand improvement may be needed to release the existing desirable species from competition and to remove the less desirable vegetation (Klapproth 2001). The strategy against invasive plants is to replace the invader, not temporarily remove it (Dozier 2000).

In a study conducted by D. P. Pannill et al. in 2001, they found that problems with weed control sufficient to affect the survival and growth of planted trees were very common. Weeds or vines were the most significant problem, found on half the plots. Other

problems affecting 3 to 6 percent of the plots were deer, mechanical damage from mowing, shading from adjacent trees, insects, and poor planting practices. They found that maintenance practices, such as



mowing and herbicide spraying are important for adequate survival, with a combination offering the greatest survival. Herbicides were more cost-effective on larger restoration sites. Using native plants that are tolerant of herbicide overspray was also recommended. Dozier et al. in 1998 agreed, stating that using a mixed management approach that employs chemical and mechanical control methods may be the best means of insuring long-term success. Reliance on a single type of control method may be prohibitively expensive or result in failure against aggressive invasive plant species. Integrated management also includes replanting the site with suitable species, so that the invasive species does not return. Establishment of desirable plant species is essential for long-term control on the restoration site (Dozier et al. 1998, Taylor and McDaniel 1998).

## **FUTURE RESEARCH NEEDS**

Based on research and other literature presented in this paper, there are many questions concerning natural and artificial regeneration of riparian forest buffers. In the study conducted by Pannill et al., the need for further study was indicated on several topics including the relative merits of tree shelters by species, and the relative merits of using certain species as they relate to site conditions and herbivore density. Other study needs include the merits of

various methods of site preparation and maintenance practices on growth and survival, especially influences of previous land use, and the merits of various methods of planting on survival, including hand vs. machine, volunteers vs. contractors, etc. Several state forestry departments identified the need for information on management options for naturally-regenerated buffers, as well as options available for planting buffers with their costs and benefits. Some of this work is in the process of being completed.

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