SUCCESS OF RIPARIAN RESTORATION PROJECTS IN THE MOUNTAINS, PIEDMONT, AND COASTAL PLAIN OF VIRGINIA

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Abstract—Forested riparian buffers are a Best Management Practice (BMP) for protection of water quality and for habitat. Since the 1990s, conservation agencies in Virginia have been involved in establishment of riparian buffers under the auspices of programs such as the Conservation Reserve Enhancement Program (CREP). Although CREP was established for protection of water quality, little monitoring has evaluated the success of establishment efforts. In summer 2006, we evaluated 63 CREP sites located in the Coastal Plain, Piedmont, and Ridge and Valley regions. Overall, riparian forests in the Coastal Plain and Piedmont were well stocked due to a combination of planted and natural regeneration. In general, the Ridge and Valley sites were not well stocked and sites had problems with invasive, exotic species. Our findings indicate that additional efforts should be made to ensure fencing is maintained, species selections are based on site conditions, and invasive species are controlled.

INTRODUCTION

Riparian forests have numerous societal values including the protection of water quality (shade, nutrient uptake, storage and transformation, sediment trapping, streambank stability, and detritus/course woody debris export) and habitat (linear corridors, landscape diversity, stream habitat) (Castelle and others 1994, Daniels and Gilliam 1996, Klapproth 1996, Verry and others 2000, Walbridge 1993, Welsch 1996).

Approximately 87 percent of the riparian forests in the Eastern United States have been deforested, primarily for agricultural production (Allen and others 2001). Over the past decade numerous programs have been developed for restoration of these important riparian ecosystems on areas that had previously been deforested for agricultural or urban activities (Allen and others 2001). Agricultural use includes crop production, livestock grazing, and open pasturelands. These agricultural lands provide significant amounts of nonpoint source pollution to the watersheds draining into the Chesapeake Bay as well as the southern rivers of the United States. Excessive nutrients from livestock wastes, sediment runoff of erodable grounds, and runoff from chemical applications are all examples of contaminants exuded from agricultural lands (Gianessi and others 1985).

The reestablishment of riparian forests is an agricultural Best Management Practice that is often recommended for the improvement of water quality and the establishment of habitat. Several federal conservation programs exist that attempt to entice farmers to remove acres of land adjacent to watersheds from production to be used for the reestablishment of riparian forests. The Virginia Department of Forestry (VDOF) has been involved in hundreds of restoration projects in the agricultural setting. In 2004-2005 the VDOF established over 600 miles of riparian forests, primarily as part of the Conservation Reserve Enhancement Program (CREP) plantings. However, they are concerned because they have little data to document that the reestablishment plantings have survived.

The goal of this project was to examine restoration plantings across the Coastal Plain, Piedmont, and Ridge and Valley regions of Virginia in order to determine which species survived best, which planting techniques worked best, and if the plantings are adequately stocked.

METHODS

Study Site

The study sites were selected randomly from VDOF conservation programs database. Selections were weighted based on the total amount of acres planted in each physiographic region. A total of 63 sites were sampled, 16 in the Coastal Plain, 23 in the Piedmont, and 24 in the Ridge and Valley physiographic regions of VA. Sites were typically located adjacent to ephemeral, intermittent, or perennial streams, in agricultural settings and parallel to crop production fields or livestock grazing fields.

Field Methods

County VDOF foresters provided information from landowner files pertaining to the selected sites visited in the study. These files were examined for information such as the planting density, species planted, contractor information, year planted, age of planted seedlings, site preparation treatments, competition control, establishment techniques (planting tubes, planting mats, fencing), and maps of the site locations. In addition, landowners, when available, were interviewed regarding any maintenance or replanting conducted on the site and the number and type of grazing animals located near the site.

Field data at each site were collected using fixed area plots. The sample plot size was dependent upon the size of the site; the plots used in the study ranged from 1/1000th acre to 1/10th acre. For each plot the radius, landform (floodplain, toe slope, terrace, sideslope, upland), distance from stream (if applicable), and herbaceous competition data were recorded. The type, size, and color of any planting tubes used at each site were recorded for each tree. The adequacy of any

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fencing structures was also noted. The stream periodicity, when applicable and present, was identified as perennial, intermittent, or ephemeral. Individual tree data for both planted and volunteer species were recorded at each plot. Individual tree data consisted of recording the use of any planting aids (tubes, mats, or fencing), tree or shrub species, vigor (dead, poor, moderate, good), height (feet), diameter at breast height (inches, where applicable), and any comments indicating important information associated with the plot.

Statistical Analysis

Data collected in this study were analyzed using Minitab 14 Statistical Analysis Program, and Number Cruncher Statistical System. Using the data collected from the 63 sites the response variables such as tree stocking and growth characteristics were analyzed by region using the Kruskal-Wallis One-way ANOVA procedure.

RESULTS AND DISCUSSION

The Coastal Plain region had the highest stocking of planted trees with a mean of 115 trees per acre and the highest average naturally regenerated species of 3 162 per acre (table 1). These means decreased as the study sites progressed westward across the state through the Piedmont and Ridge and Valley regions. The Piedmont averaged 99 trees per acre of surviving planted trees and an average 1 082 trees per acre of volunteers, while the Ridge and Valley produced averages of 85 and 185 trees per acre, respectively. The average percent stocking for the Coastal Plain, Piedmont, and Ridge and Valley were 100, 90, and 77 percent, respectively. The percent stocking was based on the Natural Resource Conservation Guideline of planting 110 trees per acres. In combination with the planted stems, the Coastal Plain and Piedmont are very well stocked and should provide good composition throughout the establishment and growth of the stand (tables 2, 3). However, the Ridge and Valley region generally had poor stocking and efforts need to be applied to provide better survival and stocking rates. One characteristic attributing to this region's lack of stocking is the lack of a volunteer seed source. Many of the sites planted in the Ridge and Valley were in the middle of large pastures where trees, especially the pioneer species, were absent.

Several difficulties were encountered throughout the study; one commonly being the lack of information pertaining to the original species planted and their location on the planted sites. The mean stocking values for species listed in table 2 are solely based on the species that were present and identifiable during the study. The planted species, having lower stocking values in each region, were most commonly soft mast species including: black cherry (*Prunus serotina*), common apple (*Malus* spp.), crab apple (*Pyrus coronaria*), flowering dogwood (*Cornus florida*), hackberry (*Celtis occidentalis*), persimmon (*Diospyros virginiana*), and redbud (*Cercis canadensis*). The species having the best stocking for each of the regions were oaks. The best performers in the Coastal Plain region were black oak (*Quercus velutina*) and willow oak (*Quercus phellos*) (both ranked in first place). These species were followed closely by pin oak (*Quercus palustris*) and white oak (*Quercus alba*), in second and third place, respectively. The top surviving species in the Piedmont were southern red oak (*Quercus falcata*), with pin oak and white oak as the subsequent survivors. The lead survivors of the Ridge and Valley region were white oak followed by northern red oak (*Quercus rubra*) and pin oak in second and third place respectively. In each region oaks made up over 60 percent of the average surviving trees. Pin oak, willow oak, white oak, and northern red oak, along with green ash were the five most commonly observed species out of the 63 sites in the study. Having this exceptional oak stocking and dominance is good for hard mast production and long-term tree cover, but if the objective is water quality improvement and protection, then faster growing species may be more desirable.

The naturally regenerated species recorded in this study present competition for nutrients, sunlight, and water for the planted species. At the same time these volunteers are a key attribute to the riparian area and the naturally regenerated species provide many of the same functions as the planted species. The Coastal Plain was excessively dominated by sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubra*), and loblolly pine (*Pinus taeda*) as the first, second, and third most frequently tallied volunteers (table 3). Sweetgum comprised approximately 40 percent of the average total stocking. Sweetgum, red maple, and loblolly pine comprise over 85 percent of the mean natural regeneration in the

Table 1—Mean stocking and survival of planted and volunteer for each physiographic region studied in Virginia

Physiographic Regions	Mean planted trees/acre	Median planted trees/acre	Average percent survival	Mean naturally regenerated trees/acre	Median naturally regenerated trees/acre	Mean Total trees/acre
Coastal Plain	115a	91a	100	3162b	928.6b	3277
Piedmont	99a	90a	90	1082ab	540a	1181
Ridge and Valley	85a	77.5a	77	185a	38.5a	270
Mean of all regions	99.6		89	1476		

*A number followed by an “a” is significantly different (alpha = 0.1).

Table 2—Mean surviving planted trees per acre by species ranked from most prevalent, 1, to least prevalent in each physiographic region studied in Virginia. Species ranked below 10 were not included

	Coastal Plain		Piedmont		Ridge and Valley	
Species	Mean trees/ acre	Rank	Mean trees/ acre	Rank	Mean trees/ acre	Rank
American sycamore (*Platanus occidentalis*)	4.6	6	0.1	21	1.8	10
Baldcypress (*Taxodium distichum*)	2.4	11	4.3	8	2.8	7
Black oak (*Quercus velutina*)	17.2	1	0.4	19	5.4	5
Chestnut oak (*Quercus prinus*)	—	—	—	—	3.1	6
Common apple (*Malus* spp.)	4.7	5	0.4	19	0.6	17
Eastern white pine (*Pinus strobus*)	—	—	—	—	1.8	10
Green ash (*Fraxinus pennsylvanica*)	2.4	11	6.2	6	7.3	4
Northern red oak (*Quercus rubra*)	2.8	10	6.1	7	11.4	2
Pin oak (*Quercus palustris*)	15.0	2	12.9	2	9.0	3
Red osier dogwood (*Cornus sericea*)	3.2	9	—	—	—	—
Southern red oak (*Quercus falcata*)	3.5	8	15.2	1	—	—
Sawtooth oak (*Quercus acutissima*)	3.6	7	7.3	5	1.5	12
Swamp chestnut oak (*Quercus michauxii*)	10.6	4	1.3	14	2.3	9
White oak (*Quercus alba*)	12.5	3	10.4	3	22.7	1
Willow oak (*Quercus phellos*)	17.2	1	10.1	4	2.7	8
Yellow poplar (*Liriodendron tulipifera*)	0.9	15	2.6	10	0.3	18
Grand Total	107	—	94	—	82	—

Table 3—Mean naturally regenerated trees per acre by species ranked from most prevalent, 1, to least prevalent in each physiographic region studied in Virginia. Species ranked below 10 were not included

	Coastal Plain		Piedmont		Ridge and Valley	
Species	Mean trees/acre	Rank	Mean trees/acre	Rank	Mean trees/acre	Rank
American sycamore *(Platanus occidentalis)*	27.6	8	3.6	20	—	—
Ailanthus *(Ailanthus altissima)*	—	—	8.8	14	41.9	1
Autumn olive *(Elaeagnus umbellata)*	—	—	0.3	29	25.0	3
Black cherry *(Prunus serotina)*	19.3	9	13.4	12	—	—
Black walnut *(Juglands nigra)*	0.3	17	8.8	14	1.7	8
Boxelder *(Acer negundo)*	4.6	14	190.4	3	35.6	2
Coralberry *(Symphoricarpos orbiculatus)*	—	—	33.6	7	4.3	7
Crab apple *(Pyrus cornaria)*	—	—	—	—	1.5	9
Eastern redcedar *(Juniperus virginiana)*	122.0	4	76.3	5	18.6	4
Groundsel tree *(Baccharis salicifolia)*	79.4	6	—	—	—	—
Hazel alder *(Alnus serrulata)*	—	—	39.1	6	—	—
Honey locust *(Gleditsia triacanthos)*	—	—	1.9	24	1.4	10
Loblolly pine *(Pinus taeda)*	441.9	3	2.3	22	—	—
Persimmon *(Diospyros virginiana)*	9.2	12	9.8	13	1.5	9
Red maple *(Acer rubrum)*	1117.7	2	264.1	1	5.8	5
Red osier dogwood *(Cornus sericea)*	—	—	—	—	4.9	6
River birch *(Betula nigra)*	16.7	11	0.3	29	—	—
Silky dogwood *(Cornus amomum)*	—	—	—	—	1.7	8
Slippery elm *(Ulmus rubra)*	—	—	22.7	9	1.1	11
Sweetgum *(Liquidambar styraciflua)*	1407.7	1	28.4	8	—	—
Waxmyrtle *(Morella cerifera)*	18.3	10	—	—	—	—
Winged elm *(Ulmus alata)*	—	—	17.4	10	—	—
Winged sumac *(Rhus copallinum)*	119.3	5	—	—	—	—
Yellow poplar *(Liriodendron tulipifera)*	65.1	7	193.5	2	—	—
Grand Total	3472	—	1128	—	154	—

Table 4—Corresponding means ranges, and percentages of multiple parameters noted at each site for each physiographic region of Virginia in the study

		Coastal Plain		Piedmont		Ridge and Valley	
		Average	Range	Average	Range	Average	Range
General Information	Size (acres)	10	1.5 - 50	12.3	1.6 - 93	10.4	2 - 30
	Age (years)	2.25	1 - 5	2.6	1 - 5	3.2	1 - 5
	Contractor planted	—	15	—	23	—	26
	Landowner planted	—	1	—	0	—	0
	Planted density	163	110 - 440	110	110	113	110 - 193
Planting aids	Use of tubes (%)	—	81.20%	—	100%	—	100%
	Use of mats (%)	—	75%	—	95.6%	—	100%
	Use of fencing (%)	—	12.5%	—	78.2%	—	92.3%
	Tube height (feet)	3.2	0 - 4	3.2	2 - 4	3.0	2 - 4
Site prep:	Mowed (%)	—	6.25%	—	8.7%	—	3.8%
	Herbicide sprayed (%)	—	12.5%	—	4.3%	—	0%
Maintenance:	Mowed (%)	—	12.5%	—	13%	—	46.1%
	Good fence maintenance (%)	—	25%	—	82.6%	—	79.2%
	Moderate fence maintenance (%)	—	—	—	4.3%	—	4.2%
	Poor fence maintenance (%)	—	—	—	4.3%	—	4.2%

Coastal Plain. The Piedmont was also dominated by red maple, where it was the most commonly regenerated species followed closely by yellow poplar (*Liriodendron tulipifera*) and boxelder (*Acer negundo*). The Ridge and Valley's most common natural regeneration were ailanthus (*Ailanthus altissima*) followed by boxelder and autumn olive (*Elaeagnus umbellata*). The Ridge and Valley has low planting survival and these data indicate that two of the most common naturally regenerated species are invasive species. Ailanthus and autumn olive are generally considered to be non-desirable invasive exotic species. Control measures, such as herbicide applications, may be necessary in order to contend with these invasives and promote the growth of the planted species or more desirable volunteer species. However, herbicide use must be judiciously applied due to the location of these plantings near streams.

Planting tubes are a common planting aid used in these hardwood plantings to protect the seedlings from vegetative competition, animal consumption, and to provide a better growing climate for the seedlings. Three planting tubes sizes were found on the study sites. These tube sizes included 2-, 3-, and 4-foot tubes along with three sites in the Coastal Plain where no tubes were used. We found no statistically significant difference in height growth between the 2-, 3-, and 4-foot tubes. Out of the 63 sites sampled 15 sites used 2-foot tubes, 32 sites used 4-foot tubes, and 13 sites used 3-foot tubes. From an economic viewpoint, it may be just as effective for survival to use the cheaper 2-foot tubes rather than the more expensive 4 foot tubes. As only three examples were found where no tubes were used comparison of tubes with no-tubes were not appropriate. Therefore, it is unknown how effective this type of planting method may be in the Piedmont or Ridge and Valley, but it may provide for an interesting study in these two regions. Stuhlinger and others (2007) found that three different types of 4-foot tubes provided no effect on overall seedling survival of green ash or cherrybark oak, but unsheltered trees had stunted growth due to deer browse.

When available, additional parameter data were collected and this data is displayed in table 4. Interestingly, very few sites had any type of site preparation activities conducted to better prepare the site for planting. It is suspected that mowing would be the more common site preparation technique due to the availability of mowing equipment at the planting sites and the complications of using herbicides near open waters. The Coastal Plain did have the highest (12.5 percent) amount of site preparation conducted with herbicide application, while the Piedmont had the highest (8.7 percent) amount of site preparation done by mowing. Only 4 of the 16 sites in the Coastal Plain had fencing present, each being in good condition. Only 2 of the 23 sites in the Piedmont and 3 of the 24 sites in the Ridge and Valley did not have fencing present during the study. Out of the 63 sites sampled, 6 had livestock inside the planting area and caused devastating damage to the site. Some routine mowing maintenance was conducted on various sites and, as indicated in table 5, nearly 50 percent of the sites in the Ridge and Valley were mowed to control vegetative competition. This maintenance could potentially improve the growth of the planted seedlings. However, mowing grass in filter strips may decrease the sediment trapping.

Damaging factors that would alter or inhibit growth tree growth were noted (table 5). These damaging agents affected not all trees in the study, but multiple damaging agents also affected trees. The most common damaging agents involved the planting aids. The highest occurring issue for Coastal Plains and the Ridge and Valley was the tube being knocked down on the ground providing no protection to the seedling from animal consumption, human influences, or insect damage. In the Coastal Plain, 40.1 percent of the damages were due to the tube being down on the ground while missing tubes made up 25 percent and bent tubes made up 18.7 percent of the affected seedlings. Missing tubes made up the largest percent of issues in the Piedmont with 32.4 percent of the plantings missing tubes, while 19 percent of the plantings involved bent tubes. Only 17.1 percent of the plantings in the Piedmont had tubes down on the ground. The Ridge and Valley had 30.5 percent of plantings with the tubes down on the ground and 29.5 percent with missing tubes. Deer browse, though relatively low in the Coastal Plain (9.4 percent) and Piedmont (11.4 percent) made up the third highest damaging agent in the Ridge and Valley (16.7 percent). The use of 2 foot tubes in the Ridge and Valley, placing the plant at deer height for consumption may have been a contributing factor, but the data cannot support this conclusion. Overall planting aid issues comprised 83.8 percent of the problems in the Coastal Plain, 77.1 percent in the Piedmont, and 74.25 percent in the Ridge and Valley. These issues were followed closely by animal and insect damages comprising 12.5, 20, and 23.8 percent of the problems for each region respectively. Human influences including herbicide over-spray and mowed tubes only accounted for about 8 percent of the total damages in all three of the regions combined. Vegetative influences entailing overtopping vegetation had the least percent of damage on only the Piedmont and Ridge and Valley regions amounting to a mere 3.3 percent.

SUMMARY

Restoration of riparian forest vegetation via plantings is generally successful in situations having a combination of good fencing, proper species selection, and the proper installation of planting aids. The Coastal Plain and Piedmont efforts are working primarily due to the fencing out of livestock and the abundance of volunteer growth. Efforts in the Ridge and Valley need to be focused more on the control of invasive species so the desired vegetative cover is achieved. In order for these restorations to work effectively, clearly defined objectives need to be set forth for the administration of these plantings. If the improvement of water quality is the main objective of this restoration effort, then a combination of both hardwood and softwood species would likely be more effective than the use of soft mast species. The oaks used on these CREP sites are slow growing and will provide for a future stand in the long run. For the short-term, faster growing species could be selected to provide a rapid site establishment and better initial water quality improvement. Proper species selection should involve the evaluation of natural vegetation on the site and the species then selected from that composition. A combination of both

Table 5—Damaging agents with their percent occurrences ranked in each physiographic region

	Coastal Plain		Piedmont		Ridge and Valley	
Damaging agents	Percent	Rank	Percent	Rank	Percent	Rank
Deer browsed	9.4	4	11.4	4	16.7	3
Groundhog hole at base	—	—	—	—	0.95	8
Herbicide over-sprayed	—	—	0.9	11	0.95	9
Growing outside tube	—	—	4.8	6	0.95	10
Holes pecked in tube	—	—	—	—	0.95	11
Japanese beetle damage	3.1	5	8.6	5	5.2	5
Mat missing	—	—	2.8	7	—	—
Overtopping vegetation	—	—	1.9	8	1.4	6
Tube bent	18.7	3	19.0	2	11.9	4
Tube damaged	—	—	1.0	10	1.4	7
Tube down on ground	40.1	1	17.1	3	30.5	1
Tube missing	25	2	32.4	1	29.5	2
Tube mowed	3.1	6	1.9	9	.95	12

slow and fast growing species may provide for the best stand establishment.

Planting shelters are contributing to the growth and survival of these plantings, however, the data indicate that the less expensive 2 foot tubes may be just as effective as the 3- and 4-foot tubes, although the deer browse issue is site dependent. Having had few sites with site preparation techniques applied, it may be appropriate to look more closely into better site preparation techniques to more sufficiently establish the initial seedlings' growth. The majority of the damaging issues involved the planting shelters affecting the seedling's growth. In order to address these problems, some amount of inspection and maintenance should be conducted on the planted sites. Landowners and/or agency officials should routinely observe the plantings to confirm that the survival and stocking is adequate and the fencing is keeping the livestock out. Finally, better performance may be achieved through landowner education by the designated agencies and officials.

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LITERATURE CITED

Allen, J.A.; Keeland, B.D.; Stanturf, J.A. [and others]. 2001. A guide to bottomland hardwood restoration. Joint publication of the USDI US Geological Survey (Informations and Technology Report USGS/BRD/ITR-2000-0011 and US Forest Service (Gen. Tech. Rep. SRS-40). 132 p.

Castelle, A.J.; Johnson, A.W.; Conolly C. 1994. Wetland and stream buffer size requirements - a review. Journal of Environmental Quality. 23: 878-882.

Daniels, R.B.; Gilliam J.W. 1996. Sediment and chemical load reduction by grass and riparian buffers. Soil Science Society of America Journal. 60: 246-251.

Gianessi, L.P.; Peskin, H.M.; Puffer, C.A. 1985. A national data base of nonurban nonpoint source discharges and their effects on the nations water quality. Report submitted to the Office of Standards and Regulations of the U.S. Environmental Protection Agency. Renewable Resources Division, Resources for the Future, Washington, DC.

Klapproth, J.1996. The benefits of riparian buffers. Forest Landowner. 55(6): 28-31.

Stuhlinger, H.C.; Earl, J.A.; Montgomery, R.A. 2007. The effects of tree shelters on seedling survival and growth of two bottomland hardwood species: third-year results. Fourteenth Biennial Southern Silviculture Research Conference, Athens, GA. February 26-March 1, 2007.

Verry, E.S.; Hornbeck, J.W.; Dolloff, C.A. (eds.). 2000. Riparian Management in Forests of the Continental Eastern United States. Lewis, Publishers, New York: 402 p.

Walbridge, M.R. 1993. Functions and values of forested wetlands in the southern United States. Journal Forestry. 91(5): 15-19.

Welsch, D.J. 1996. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA Forest Service, Northeastern State and Private Forestry, NA-PR-07-91. Government Printing Office, Washington, DC. 20 p.