Powell River Project Series

Information for the Virginia Coalfields

Recovery of Native Plant Communities after Mining

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Introduction

Coal surface mining and mine reclamation have had a significant impact on the landscape throughout the Appalachian region, including southwestern Virginia's coalfields. This fact is recognized by the Surface Mining Control and Reclamation Act (SMCRA), which states that mining operations shall establish "a diverse, effective, and permanent vegetative cover of the same seasonal variety and native to the area ... and capable of self-regeneration and plant succession ..." [Section 515(b)19], unless introduced species are necessary to achieve the post-mining land use. Restoring the native hardwood forest is the most direct and comprehensive way of meeting this premise of SMCRA in Appalachian landscapes. Re-establishment of this self-sustaining ecosystem on reclaimed mines can aid in maintaining native wildlife populations while providing other valuable ecosystem services, such as erosion control, carbon sequestration, wood production, water-quality improvement, and watershed protection. Re-establishment of native hardwood-forest ecosystems also contributes to the natural beauty of the Appalachian region.

This publication summarizes research on the impacts of reclamation practices on re-establishment of native Appalachian forest ecosystems, and describes practices that may be used during reclamation to encourage re-establishment of native hardwood forest plant communities.

Appalachian Forest Ecosystems

The mixed mesophytic hardwood forest of the central Appalachians is one of the most diverse temperate ecosystems. These forests served as refuge for moist-forest species during drier glacial epochs and, therefore, are home for a large number of species. The forests often host up to 25 tree species in a given area, along with a diverse understory of ferns, fungi, and herbaceous plants. Common tree species, such as oaks (*Quercus* spp.), maple (*Acer* spp.), hickory (*Carya* spp.), and tulip poplar (*Liriodendron tulipifera*), not only provide habitat for a wide range of bird, amphibian, and wildlife species, but are also commercially valuable. These forests play an important role in maintaining the water quality in nearby streams including southwest Virginia's Clinch - Powell river system which hosts numerous endemic species of mussels, fish, and crayfish, and is among the most diverse temperate freshwater ecosystems. Large areas of Appalachian forest have been cleared for agriculture and other human uses. Continuous tracts of forest are important for conservation of animal and plant species.

Changing Reclamation Practices over Time:

Prior to SMCRA, mine reclamation practices were variable and often resulted in exposed highwalls, unstable outslopes, and low ground cover. During the earliest surface mining, very little reclamation was performed. Between 1972 and 1977 in Virginia, most mined areas were seeded with grasses, clovers, and black locust (*Robinia pseudoacacia*); eastern white pine (*Pinus strobus*) was often planted along the top of the outslope in an effort to disguisehide the exposed highwalls. With the passage of the Surface Mining Control

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and Reclamation Act (SMCRA) in 1977, reclamation practices were mandated and standardized. SMCRA required that the approximate original contour of the mined area be restored, and that reclaimed areas be seeded with herbaceous vegetation to minimize erosion and to achieve the 90% ground cover after five years. Many post-SMCRA mined areas throughout the Appalachians were reclaimed to hayland - pasture postmining land uses; reclamation practices on these areas included use of aggressive groundcover vegetation such as Kentucky 31 tall fescue (*Festuca arundinacea*) and sericea lespedeza (*Lespedeza cuneata*). Many of these areas, however, were not used for production of hay or pasture, allowing natural ecosystem succession processes to take place. During the late 1980s and early 1990s, reclamation of mined areas to unmanaged-forest postmining land use became more common, especially in Virginia. These areas were often seeded with the same aggressive groundcovers that are effective in creating hayland - pasture, such as Kentucky 31 tall fescue and sericea lespedeza. Black locust was often seeded with herbaceous groundcover, and eastern white pine was planted as two-year old seedlings. In the mid- and late-1990s, some mining operators began using less competitive ground covers, as described by Burger and Torbert (1993), and a wider range of planted tree species, including hardwoods, to produce forested areas.

Because success of reclamation is normally judged after five years, reclamation efforts often focus on short-term results and bond release. When the mining is conducted on a pre-SMCRA abandoned mine site, the liability period can be as short as two years. After final bond release, most post-mining lands receive little management and go through succession, the process by which species slowly replace one another as the community develops toward a relatively stable species composition called climax vegetation.

There is an increasing interest in restoring Appalachian forest ecosystems after mining. Yet, there have been few studies monitoring long-term vegetation recovery on coal surface mined lands reclaimed in the Appalachian region using different reclamation practices. Holl surveyed the trees, shrubs, and herbs on 15 reclaimed mine sites and five unmined hardwood sites in Wise County, Virginia, during the summers of 1992-1993 and again in summer 1999 (Holl and Cairns 1994; Holl 2000). A summary of that research is presented below, along with a description of reclamation practices that may be used to aid recovery of the native hardwood forest plant community.

Research Summary

Study Sites

Twenty 0.6-acre plots were surveyed during summer 1992/1993 and summer 1999. These included:

- 5 sites reclaimed 1980-1987
- 5 sites reclaimed 1972-1977
- 5 sites reclaimed 1967-1972
- 5 unmined hardwood forest sites ("reference sites")

The majority of the sites are located on or near the Powell River Project Education Center. The other sites are located near the town of Appalachia. All sites are on steep south-facing slopes, ranging in elevation from 2300 to 3030 ft. Vegetation was sampled in three layers: herb (up to 2.5 feet tall); shrub (2.5 - 8.2 feet tall); and tree (taller than 8.2 feet). Sampling techniques followed those outlined in Holl and Cairns (1994). Cover and number of species were measured in both years and compared.

Summary of Research Results:

Herbaceous layer

In the 1992-93 surveys, herbaceous groundcover was greater than 80% in sites reclaimed after 1972 (Figure 1A). Herbaceous cover dropped substantially between 1992-93 and 1999 on the 1980-87 reclamation sites due to shading by white pine, and on the 1972-77 reclamation sites due to shading by red maple (*Acer rubrum*), sweet birch (*Betula lenta*), and other trees. The shift in herbaceous cover to tree cover was interpreted as resulting from the absence or decline of species that compete with small tree seedlings for light and nutrients, such as sericea lespedeza, orchard grass, and Kentucky 31 fescue, and the reduced density of early-successional species such as aster and goldenrod species (*Aster* spp., *Erigeron* spp., *Hieracium* spp., and *Solidago* spp.). Herbaceous groundcover on the 1967-72 sites was intermediate (about 60%) and changed little between the sampling periods.

During the time period between the two vegetation samples, the number of naturally-colonizing herb species on the 1972-77 and 1980-87 reclamation sites declined, while the number of species growing in the oldest reclaimed sites remained higher (Figure 1B). The decrease in species growing on the 1972-77 and 1980-87 reclamation sites is surprising as species numbers usually increase early in the forest development process. A number of forest herbs such as wild geranium (*Geranium maculatum*), snakeroot (*Sanicula canadensis*), and galax (*Galax aphylla*) are found on the oldest reclaimed sites but not on those reclaimed more recently. The lower number of naturally colonizing herb species on the 1972-77 and the 1980-87 reclaimed mine sites may be due to the more aggressive ground covers commonly planted by mining operators during those periods, and the invasion of sericea lespedeza from other reclaimed mine sites into planted covers. Another possible explanation could be the larger scale of mining, which resulted in increased distances to seed sources.

Trees

The largest increase in tree basal area between sampling periods occurred on the 1980-87 reclamation sites as they were planted primarily with eastern white pine, a fast-growing species (Figure 2A). Tree basal area also increased on the other reclaimed sites due to colonization and growth of hardwood species. The number of tree and shrub

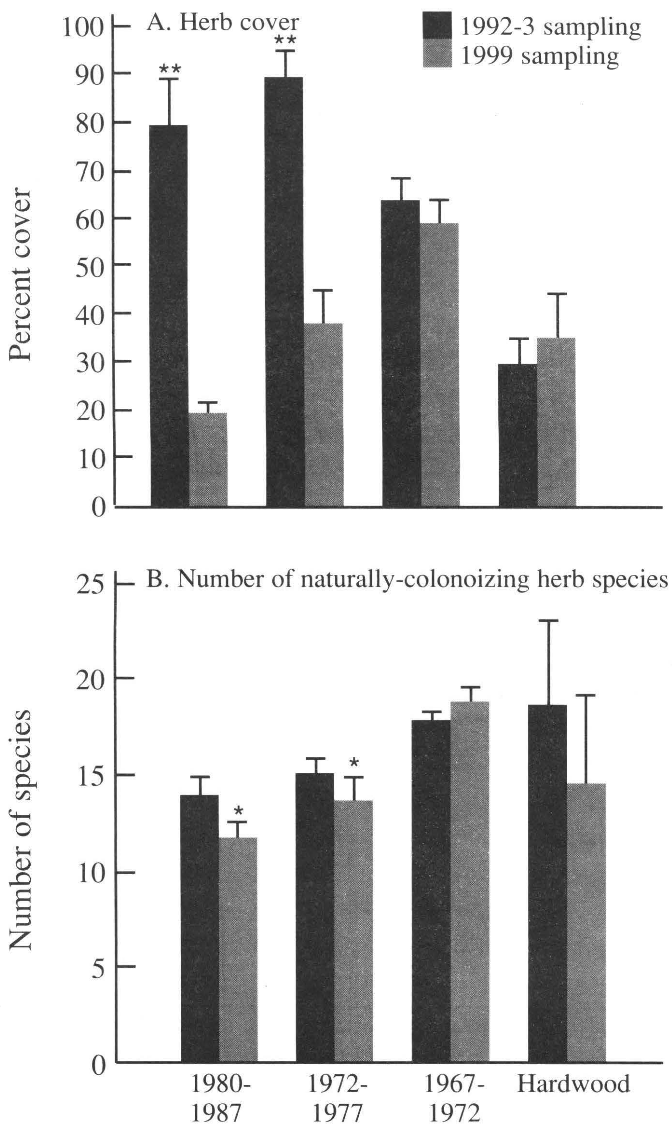

Figure 1. Average herbaceous cover and number of naturally-colonizing herb species.
Error bars = 1 SE. *=p<0.05, **=p<0.01 for comparisons between years.

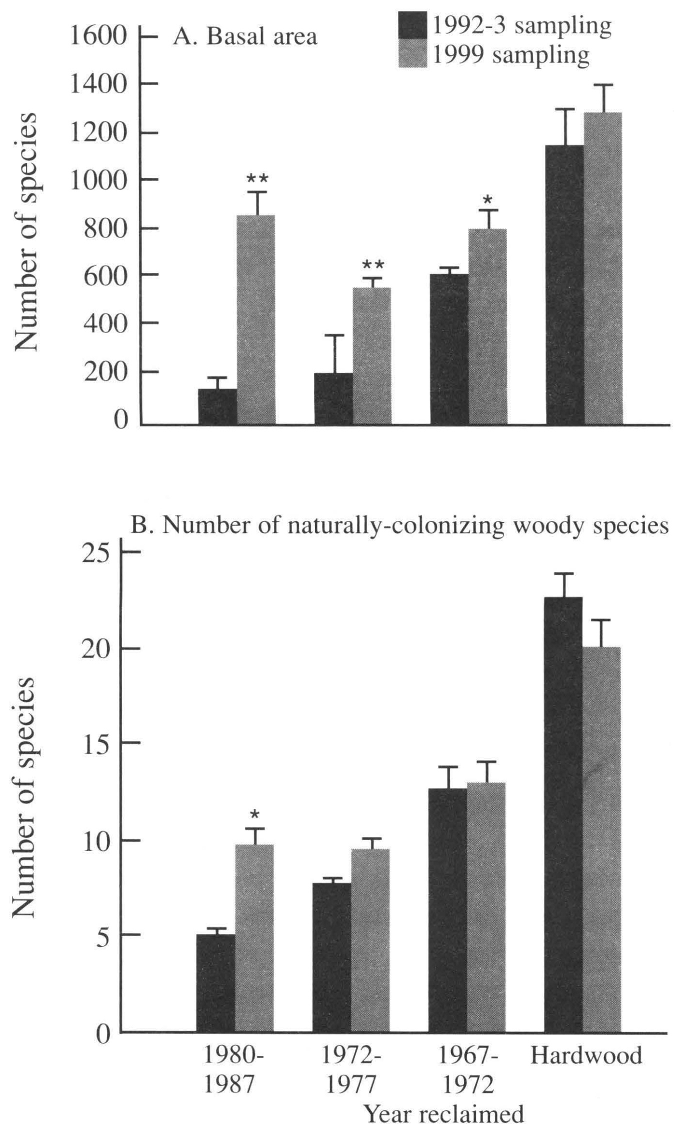

Figure 2. Average herbaceous cover and number of naturally-colonizing tree and shrub species.
Error bars = 1 SE. *=p<0.05, **=p<0.01 for comparisons between years.

species present increased on the most recently reclaimed sites (Figure 2B) with common colonizing species including red maple, sourwood (*Oxydendron arboreum*), and tulip poplar (*Liriodendron tulipifera*). Interestingly, the number of woody species on the oldest reclaimed sites remained well below the hardwood sites and did not increase (Figure 2B), raising the question of how long it will take before the full suite of tree species is established.

Overall species composition

A total of 102 native species naturally colonized reclaimed mine sites, indicating that reclaimed mines host a wide diversity of plant species. A full species listing will be made available in the internet version of this publication. Most (75%) of the native tree and shrub species and 65% of the native herbaceous species found in surveys of forest sites were also found on reclaimed mined sites (Tables 1 and 2). Moreover, a large number of herbaceous species, primarily early-successional, were found on reclaimed mine sites but not in the forest. While most common forest species were present on the reclaimed sites, some species, such as the herbs trilium (*Trilium grandiflorum*), wintergreen (Gaultheria procumbens), and bellwort (*Uvularia pudica*), and the trees Frasier's magnolia (*Magnolia frasieri*) and serviceberry (*Amelanchier arborea*) were not found on any of the reclaimed mines. These species may or may not establish themselves eventually on the mined sites, depending on the extent to which soil properties may have been altered by the mining and reclamation practices.

Table 1.
Common species observed on reclaimed and forest sites.*

Species/	Type of Reclamation			
Species Type	1980-87	1972-77	1967-72	Forest
Planted				
K-31	✓	✓		
Sericea lespedeza	✓	✓		
Red top			✓	
Orchard grass	✓			
Clover	✓	✓	✓	
Birdsfoot trefoil	✓			
Black locust	✓	✓		
White pine	✓			
Understory Herbs				
Goldenrod	✓	✓	✓	✓
Heart-leaved aster	✓		✓	✓
Frost aster	✓	✓	✓	
Violets	✓	✓	✓	✓
Avens			✓	✓
Jewel weed		✓	✓	
Christmas fern	✓	✓	✓	✓
Five-fingers	✓	✓	✓	✓
Eupatorium	✓	✓	✓	✓
Virgin's bower	✓	✓	✓	✓
Beggar's tick				✓
Understory shrubs				
Laurel	✓			✓
Blackberry	✓	✓	✓	✓
Hydrangea			✓	✓
Virginia creeper	✓	✓	✓	✓
Rhododendron				✓
Wild grape	✓	✓	✓	✓
Sassafras	✓	✓	✓	✓
Dogwood		✓	✓	✓
Overstory				
Chestnut oak				✓
Red oak		✓	✓	✓
Wild cherry	✓	✓	✓	✓
Tulip poplar	✓	✓	✓	✓
Sweet birch	✓	✓	✓	✓
Sourwood	✓	✓	✓	✓
Hickory		✓	✓	✓
Red maple	✓	✓	✓	✓

* The complete list of species observed is posted with the internet version of this publication. (http://www.ext.vt.edu/pubs/mines/460-140/460-140.html)

Table 2.
Number of native, unplanted, herbaceous and woody (shrub and tree) species found only on reclaimed sites, forest sites, or both in surveys by Holl (2000) in summer 1992/1993 and 1999.

Sites where found	Number of native, unplanted species Herbaceous	Woody
Reclaimed only	39	5
Forest only	17	9
Reclaimed and forest	31	27
Total	87	41

Reclamation Practices to Encourage Recovery of Native Forested Ecosystems

The study discussed above is one of a few recent studies documenting long-term forest recovery on reclaimed mine sites in the southeastern United States (Thompson and others 1984; Wade and Thompson 1993; Wade and Tritton 1997; Rodrigue and Burger 2000). These studies clearly show that older reclaimed mine sites host a large percentage of the plant species found in the surrounding forest, and may even host some rare species (Wade and Thompson 1993). Together, these studies show that choice of species used for reclamation appears to influence the plant species naturally colonizing reclaimed mines, as well as the rate at which those species colonize. These results suggest practices that will encourage native forest recovery on reclaimed coal surface mines.

The following procedures are based on the study reviewed above, other research conducted by Virginia Tech researchers sponsored by Powell River Project, and related scientific literature. These procedures can be used to aid rapid re-establishment of forest ecosystems on reclaimed mine areas that are similar in character to native hardwood forests, where such re-establishment is consistent with the post-mining land use objective.

1. *Establish a Soil Medium that is Suitable for Forest Species.*

In order for mine reforestation to be successful, it is essential that the surface material have chemical and physical properties that are suitable for forest species, that surface materials have sufficient depth for rooting of forest species (at least 4 feet is recommended), and that the material be placed on the surface without excessive compaction by mining machinery such as dozers and haulers.

Prior Powell River Project publications describe these procedures in detail. VCE Publication 460-121 (Daniels and Zipper 1997) reviews general processes and procedures of soil reconstruction. VCE publication 460-123 (Burger and Torbert 1993) provides guidelines for mine reforestation, including soil reconstruction. VCE publication 460-136 (Torbert and others 1996) provides further detail on spoil selection and placement for mine reforestation.

2. *Provide Seed Sources for Recolonization by Forest Species.*

Given that most species found in the native hardwood forests are not used typically in reclamation plantings, seed dispersal is essential to re-establishment of native hardwood forest plant communities. The majority of the species observed on the older mine sites were not planted by the mining operators, which leads to the conclusion that seeds of many plant species will disperse effectively on reclaimed mines if seed sources are accessible. Mechanisms for seed dispersal include wind, animals, and soil redistribution by the mining process.

Generally speaking, maintenance of native forest close to the reclamation area will encourage recolonization by forest species. On portions of large-area permits that are far-removed from forested areas, plant species that rely on wind or animals for dispersal may not colonize as readily. When possible, retaining native forest to serve as seed sources adjacent to the mining areas, or even as remnants within the mining area where the mining plan allows, will encourage more rapid recolonization. On some re-mining sites, areas enclosed by the permit cannot be mined due to the extent of previous mining; leaving such areas in forest cover with minimal disturbance will encourage recolonization of the mined areas by forest species.

Forest soils harbor many seeds. Use of salvaged soil from the surface of forested areas in reclamation will encourage re-establishment of the forest species. In cases where a nearby area of forest is about to be mined, the soil seed bank might be spread on areas that are in the process of being reclaimed. Wade (1994) found that spreading topsoil from nearby forests on reclaimed mines introduced a large number of species, including 5 tree species, 7 shrubs, 14 grasses, and 53 forbs. In cases where complete topsoil replacement is impractical, use of some topsoil in the reclamation area will provide some seed sources, and more rapid recolonization by forest species than will no re-use of surface soil at all. Whenever possible, topsoil should be moved directly from the mining area to the reclamation area. Topsoil storage prior to respreading will cause seeds to lose viability. The longer the storage period, the greater the loss of seed viability that should be expected.

3. Use Less-Competitive Ground Cover Species

The main reclamation concern of mine operators is meeting SMCRA standards. SMCRA requires operators to plant vegetation that will minimize erosion, and return the land to a productive use. But aggressive grasses and legumes slow or prevent establishment of a number of overstory and understory species characteristic of the native Appalachian hardwood forest. Moreover, extensive research by Burger and Torbert (reviewed in VCE Publication 460-123) shows that certain ground cover species, such as Kentucky-31 tall fescue, sericea lespedeza, and red, white, and sweet clover (*Trifolium* spp.), hinder establishment of planted seedlings; general observation indicates that these species discourage invasion by woody species "volunteers" from the surrounding forest, as well. It may be that as these ground cover species die back over time more species will colonize these sites, but Holl's research demonstrates that planted grasses often provide dense cover for 15 years or more.

Research by Burger and colleagues has demonstrated that less-competitive groundcovers, such as the annual grasses foxtail millet (*Setaria italica*) and annual rye (*Secale cereale*), the perennial grasses perennial ryegrass (*Lolium perenne*) and redtop (*Agrostis gigantea*), and the legume species kobe lespedeza (*Lespedeza striata* var. Kobe) and birdsfoot trefoil (*Lotus corniculatus*) do control erosion effectively, after the first year. The oldest reclaimed sites surveyed, where there is no evidence of having been seeded in sericea lespedeza, hosted the most diverse forest species assemblages. This result suggests that planting with less aggressive species will allow a more rapid recovery of the native ecosystem than what has been observed on sites where reclamation plantings are dominated with aggressive ground cover species. Also, ground cover seeding and nitrogen fertilization rates should be kept low to allow for the colonization of other plant species.

Very little research has been conducted on the capability of groundcover species other than common forages to establish successfully and control erosion on reclaimed mine sites, or on the effect of such species on the rate of forest ecosystem reestablishment. Preliminary research suggests, for example, that some annual wildflower species such as black-eyed Susan (*Rudbeckia hirta*), cornflower (*Centaurea cyanus*), and lance-leaved coreopsis (*Coreopsis lanceolata*) establish when seeded on disturbed sites (Heckman and others 1995). Research on the use of native grasses on disturbed roadsides shows that such species can be established on highway cuts with surface characteristics similar to surface mines, but the timing of seed application and weather conditions during establishment influence seeding success, and erosion control during establishment is a concern (Booze-Daniels and others 1999).

4. Plant a variety of woody species.

In recent years, many mined acres replanted for forest post-mining land use in southwestern Virginia have been planted with a near monoculture of eastern white pine. White pine is widely planted because it is well adapted to acidic soils and grows quickly to meet the 5-year bond release requirement. The rapid biomass accumulation is compatible with timber production as a post-mining land use objective, where markets for white pine are present. However, Holl's research demonstrated that the understory of dense white-pine plantings have very low species diversity, relative to native Appalachian hardwood forests. Herbaceous ground cover in sites planted densely with white pine dropped from 80 to 20 percent over the 1993 - 1999 period as the trees matured.

There is increasing interest in diversifying planted trees because of the commercial value of hardwoods. Such diversification will have beneficial effects on wildlife communities by providing a greater variety of canopy architecture and food sources (Raifall and Vogel 1978; Fowler and Turner 1981) and allowing for establishment of native herbaceous species. For example, bird diversity on reclaimed mines has been shown to be strongly related to the structural diversity of vegetation (Karr 1968). A number of hardwood tree species that are commercially viable can be used successfully in mine reclamation (Rodrigue and Burger 2000; Torbert and Burger 2000). Although these species may grow more slowly than eastern white pine, they can be expected to provide significant income over the long-term because of the higher value of their wood (Burger and others 1998). A large number of tree species, including many species of oak, pine, and maple, as well as alder, dogwood, and walnut, are available from the Virginia Department of Forestry. Good, reputable tree planters who are familiar with planting hardwoods in viable silvicultural mixtures should be used to help ensure reforestation success.

Conclusion

Under SMCRA, current reclamation practices address short-term concerns required by law, including erosion control, acid mine drainage control where acidic strata are present, and post-mining land use establishment. Maximizing long-term ecological and economic value on these sites requires balancing short- and long-term needs. Research shows that reclaimed mines are capable of supporting forest ecosystems with levels of plant diversity that approach those of natural forests. The research reviewed above showed plant communities on mine sites reclaimed within the past 30 years developed into ecosystems that resemble the native hardwood forests. Although all species in surrounding forests were not found on the mined sites, the reclaimed-mine forests are still very young relative to the native hardwood forests which had developed over much longer time periods.

Research has shown that reclamation practices have a dramatic influence on the rate of forested ecosystem recovery on unmanaged reclaimed mine sites, and on their long-term productivity and economic value. Practices that encourage ecosystem recovery are compatible with and complementary to those that may be used to establish commercially viable, productive hardwood forests on reclaimed mine sites.

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