Virginia Cooperative Extension

PUBLICATION 460-140

POWELL RIVER PROJECT

Recovery of Native Plant Communities After Mining

Karen D. Holl, Professor, Environmental Studies, University of California-Santa Cruz
C. E. Zipper, Extension Specialist, Crop and Soil Environmental Sciences, Virginia Tech
James A. Burger, Professor Emeritus, Forestry and Soil Science, Virginia Tech

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 postmining land use. Restoring the native hardwood forest is the most direct and comprehensive way of meeting this SMCRA requirement 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 groundcover. During the earliest surface mining, very little reclamation was performed.

www.ext.vt.edu

Produced by Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, 2009

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 hide the exposed highwalls.

With the passage of 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 90 percent groundcover 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 2-year-old seedlings. In the mid- and late-1990s, some mining operators began using less-competitive groundcovers 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 postmining 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, Va., during the summers of 1992-93 and again in summer 1999 (Holl and Cairns 1994; Holl 2002). 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 the summers of 1992-93, and the summer of 1999. These included:

- Five sites reclaimed 1980-87;
- Five sites reclaimed 1972-77;
- Five sites reclaimed 1967-72; and
- Five unmined hardwood forest sites (reference sites).

The majority of the sites are located on or near the Powell River Project Research and Education Center. The other sites are located near the town of Appalachia. All sites are on steep, south-facing slopes, ranging in elevation from 2,300 to 3,030 feet. 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 sampling periods and compared.

Summary of Research Results

Herbaceous Species

In the 1992-93 surveys, herbaceous groundcover was greater than 80 percent in sites reclaimed after 1972 (figure 1, upper). 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, orchardgrass, 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 percent) 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 1, lower). 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 groundcovers 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.

Woody Species: Trees and Shrubs

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 2, upper). Tree basal area also increased on the other reclaimed sites due to colonization and growth of hardwood species. The number of tree and shrub species present increased on the most recently reclaimed sites (figure 2, lower) with common colonizing species including red maple, sourwood (*Oxydendron arboreum*), and tulip poplar. Interestingly, the number of woody species on the oldest reclaimed sites remained well below the hardwood sites and did not increase, 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 the reclaimed mine sites, indicating that reclaimed mines host a wide diversity of plant species (table 1). Table 2 lists the most common species observed. A full species listing is available in table 3. Most (75 percent) of the native tree and shrub species and 65 percent of

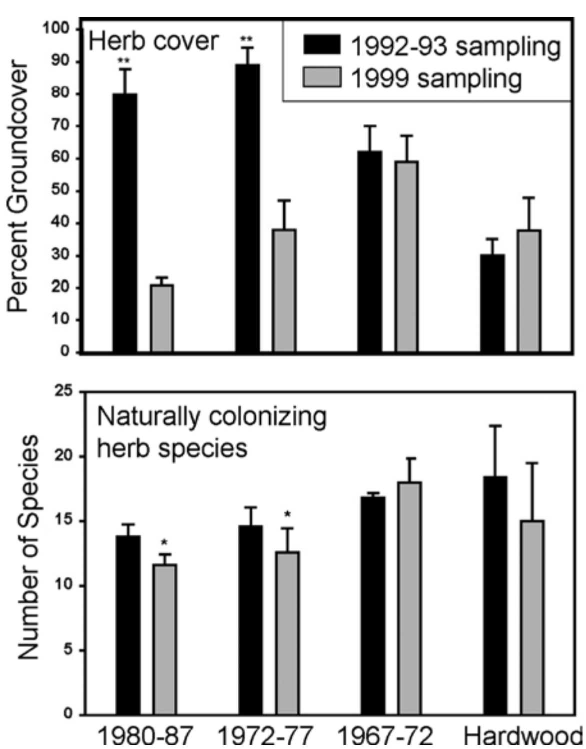

Figure 1. Average herbaceous cover and numbers of naturally colonizing herbaceous species on reclaimed lands by reclamation time period and in unmined hardwood forests. Error bars represent standard error. Asterisks represent statistical significance for comparisons between years: *(p < .05); **(p < .01).

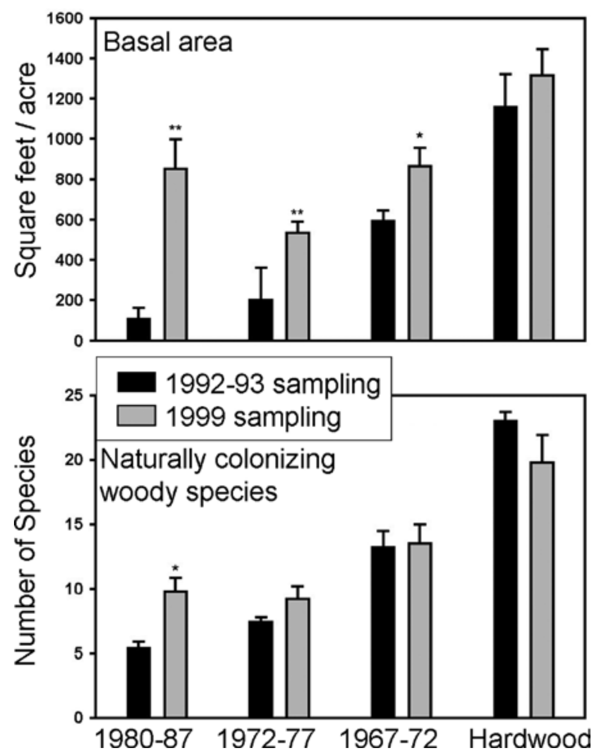

Figure 2. Average basal area by tree species (upper) and numbers of naturally colonizing tree and shrub species (lower) on reclaimed lands by reclamation time period and in unmined hardwood forests. Error bars represent standard error. Asterisks represent statistical significance for comparisons between years: *(p < .05); **(p < .01).

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. Number of native, unplanted herbaceous and woody (shrub and tree) species found only on reclaimed sites, forest sites, or on both sites, in surveys by Holl (2002) in the summers of 1992-93 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, Vogel, and Taylor 1984; Wade and Thompson 1993; Wade and Tritton 1997; and Rodrigue et al. 2002). 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.

Table 2. Common species observed on reclaimed and forest sites.*

Species/Species Type	Type of Reclamation			
	1980-87	1972-77	1967-72	Forest
Planted				
K-31 fescue	●	●		
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	●	●	●	●

* Table 3 contains a complete list of the species observed on reclaimed and forested sites.

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 postmining 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:Surface materials have chemical and physical properties that are suitable for forest species;

Surface materials have sufficient depth for rooting of forest species (at least 4 feet is recommended); and Materials 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. Virginia Cooperative Extension (VCE) publication 460-121 reviews general processes and procedures of soil reconstruction, while VCE publication 460-123 provides guidelines for mine reforestation, including soil reconstruction.

2. Provide Seed Sources for Recolonization by Forest Species

Given that most species found in native hardwood forests are not typically used 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 forests 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 remining 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 five tree species, seven 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 reuse 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, expect a greater loss of seed viability.

3. Use Less-Competitive Groundcover 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. 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 (reviewed in VCE publication 460-124) shows that certain groundcover 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 groundcover species die back over time, more species will colonize these sites, but Holl's research (2002) demonstrates that planted grasses often provide dense cover for 15 years or more.

Tree-compatible groundcovers, such as annual rye (*Secale cereale*), the perennial grasses perennial ryegrass (*Lolium perenne*) and redtop (*Agrostis gigantea*), and the legume birdsfoot trefoil (*Lotus corniculatus*) can control erosion effectively when mine soils have been left in a loose condition, without excessive compaction (VCE publication 460-124; *ARRI Forest Reclamation Advisory No. 6*). 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 groundcover species. Also, groundcover 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 to control erosion on reclaimed mine sites, or on the effect of such species on the rate of forest ecosystem re-establishment. For example, preliminary research suggests 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 et al. 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, Schmidt, and Chalmers 1999).

4. Plant a Variety of Woody Species

In southwestern Virginia during the 1990s and early 2000s, many mined acres were replanted for forest postmining land use with a near monoculture of eastern white pine. White pine was widely planted because it is well adapted to acidic soils and grows quickly to meet the five-year, bond-release requirement. The rapid biomass accumulation is compatible with timber production as a postmining land-use objective, where markets for white pine are present. However, Holl's research (2002) demonstrated that the understory of dense white-pine plantings has very low species diversity relative to native Appalachian hardwood forests. Herbaceous groundcover in densely planted sites with white pine dropped from 80 to 20 percent over the 1993-99 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 2001; Torbert and Burger 2000; see also VCE publication 460-123). 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 (VCE publication 460-138). A large number of tree species, including native hardwoods, 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 postmining 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 were still very young relative to the native hardwood forests that 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.

Acknowledgments

This project was supported by funds from the Powell River Project and the University of California-Santa Cruz. Jonathan Beals-Nesmith and Vanessa Mulkey assisted with field research.

References

Powell River Project/Virginia Cooperative Extension (VCE) publications: Available from Powell River Project (*www.cses.vt.edu/PRP/*) and Virginia Cooperative Extension (*www.ext.vt.edu*).

Burger, J. A., and C. E. Zipper. Revised 2009. *How to Restore Forests on Surface-Mined Land*. VCE publication 460-123. *http://pubs.ext.vt.edu/460-123*.

Burger, J. A., and C. E. Zipper. Revised 2009. *Maximizing the Value of Forests on Reclaimed Mined Land*. VCE publication 460-138. *http://pubs.ext.vt.edu/460-138.*

Burger, J. A., C. E. Zipper, and J. Skousen. Revised 2009. *Establishing Groundcover for Forested Postmining Land Uses*. VCE publication 460-124. *http://pubs.ext.vt.edu/460-124.*

Daniels, W. L., and C. E. Zipper. Revised 2009. *Creation and Management of Productive Minesoils*. VCE publication 460-121. *http://pubs.ext.vt.edu/460-121.*

Other References

Booze-Daniels, J., R. E. Schmidt, and D. R. Chalmers. 1999. *Evaluation and Management of Turfgrass on Virginia Roadsides*. Annual report to Virginia Department of Transportation. Department of Crop and Soil Environmental Sciences, Virginia Tech.

Brenner, F. J., R. B. Kelly, and J. Kelly. 1982. Mammalian community characteristics on surface mine lands in Pennsylvania. *Environmental Management* 6(3): 241-49.

Brenner, F. J., M. Werner, and J. Pike. 1984. Ecosystem development and natural succession in surface coal mine reclamation. *Minerals and the Environment* 6(1): 10-22.

Burger, J. A., V. Davis, J. Franklin, C. E. Zipper, J. Skousen, C. Barton, P. Angel. 2009. *Tree-Compatible Groundcovers for Reforestation and Erosion Control.* Appalachian Regional Reforestation Initiative. *Forest Reclamation Advisory No. 6* (*http://arri.osmre.gov/FRA.htm*).

Fowler, D. K., and L. J. Turner. 1981. *Surface Mine Reclamation for Wildlife: A Model Reclamation Plan for Southern Appalachia*. Fish and Wildlife Service/ OBS-81/09. U.S. Department of the Interior.

Heckman, J.R., K. Holl, M. Sabre, R. Atkinson, J. Cairns. 1996. The potential for using wildflower species to increase natural habitat in contour surface mine reclamation. pp. 453461, in: *Proceedings of the 1996 Annual Meeting of the American Society for Surface Mining and Reclamation*.

Holl, K. D. 2002. The effect of coal surface mine revegetation practices on long-term vegetation recovery. *Journal of Applied Ecology* 39:960-70.

Holl, K. D., and J. Cairns, Jr. 1994. *Vegetational Community Development on Reclaimed Coal Surface Mines in Virginia*. Torrey Botanical Club bulletin 121:327-37.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. *Condor* 70:348-57.

Raifall, B. L., and. W. G. Vogel. 1978. *A Guide for Vegetating Surface-Mined Land for Wildlife in Eastern Kentucky and West Virginia.* Fish and Wildlife Service/ OBS-78/84. U.S. Department of the Interior.

Rodrigue, J. A. 2001. *Woody Species Diversity, Forest and Site Productivity, Stumpage Value, and Carbon Sequestration of Forests on Mined Lands Reclaimed Prior to the Passage of the Surface Mining Control and Reclamation Act of 1977*. M.S. thesis. Department of Forestry, Virginia Tech.

Rodrigue, J.A., J.A. Burger, R.G. Oderwald. 2002. Forest productivity and commercial value of pre-law reclaimed mined land in the eastern United States. *Northern Journal of Applied Forestry 19*:106-114.

Thompson, R. L., W. G. Vogel, and D. D. Taylor. 1984. Vegetation and flora of a coal surface-mined area in Laurel County, Kentucky. *Castanea* 49:111-26.

Torbert, J. L., and J. A. Burger. 2000. Forest land reclamation. In: *Reclamation of Drastically Disturbed Lands*, ed. R. Barnhisle, W. Daniels, and R. Darmody. American Society of Agronomy monograph 41, 371-99.

Wade, G. L. 1989. Grass competition and establishment of native species from forest soil seed banks. *Landscape and Urban Planning* 17:135-49.

Wade, G. L., and R. L. Thompson. 1993. *Species Richness on Five Partially Reclaimed Kentucky Surface Mines*. Paper presented at the American Society for Surface Mining and Reclamation national meeting.

Wade, G. L., and L. M. Tritton. 1997. *Evaluating Biodiversity of Mineral Lands*. Paper presented at the American Society for Surface Mining and Reclamation national meeting.

Table 3. Species observed on reclaimed and forest sites.

Latin Name	Common Name	Type[1]	Year Reclaimed 1987-91	1980-87	1972-77	1967-72	Native Hardwood
HERBACEOUS							
Achillea millefolium	yarrow	N	●		●		
Adiantum pedatum	maidenhair fern	N				●	
Agrostis alba	redtop	P	●	●	●		
Agrimonia gryposepala	agrimony	N					●
Alliaria petiolata	garlic mustard	E				●	
Ambrosia artesimifolia	ragweed	E			●		
Arisaema triphyllum	Jack in the pulpit	N				●	
Asclepias syriaca	common milkweed	N					●
Asplenium platyneuron	ebony spleenwort	N	●		●	●	
Aster divaricatus	heart-leaved aster	N		●	●	●	●
Aster lateriflorus	britton	N			●	●	
Aster pilosus	frost aster	N	●	●	●	●	
Atherium asplenoides	southern lady fern	N					●
Aureolaria laevigata	smooth false foxglove	N					●
Boehmeria cylindrica	false nettle	N			●		
Botrychium virginianum	rattlesnake fern	N				●	●
Brachyelytrum erechtum		N					●
Bromus japonicus	brome grass	E		●	●		
Campanula divaricata	southern harebell	N			●	●	●
Cardamine hirsuta[2]	bitter cress	E		●	●	●	
Carex purpurifera		N					●
Carex virescens		N			●	●	
Caulophyllum thalictroides	blue cohosh	N					●
Chimaphila maculata	spotted wintergreen	N		●			
Chrysanthemum leucanthemum	ox-eye daisy	E	●	●			
Circaea lutetiana	enchanter's nightshade	N				●	●
Clematis virginiana	virgin's bower	N	●	●	●	●	●
Convolvulus arvensis	bindweed	E	●	●	●	●	
Coronilla varia	crown vetch	P	●			●	
Dactylis glomerata	orchard grass	P	●	●	●		
Daucus carota	Queen Anne's lace	E	●	●			
Dennstaedtia punctilobula	hay-scented fern	N				●	●
Desmodium nudiflorum	beggar's tick	N				●	●
Dianthus armeria	Deptford pink	E			●		
Dioscorea villosa	wild yam	N		●			●
Disporum lanuginosum	yellow mandarin	N					●
Dryopteris marginalis	marginal woodfern	N			●		

[1]N = native, E = exotic, P = planted.
[2]In 1992-93, plants were surveyed in May and August. In 1999, plants were surveyed in August only. By August, *Cardamine hirsuta* and *Galium aparine* had died, and it was impossible to identify individual species of *Viola*.

Table 3. Species observed on reclaimed and forest sites. (cont.)

Latin Name	Common Name	Type[1]	Year Reclaimed 1987-91	1980-87	1972-77	1967-72	Native Hardwood
Epilobium coloratum		N	●		●		
Epigaea repens	trailing arbutus	N					●
Erechtites hieracifolia	fireweed	N		●	●		
Erigeron annuus	daisy fleabane	N		●			
Erigeron canadensis	horseweed	N	●	●	●		
Erigeron philadelphicus	common fleabane	N		●	●		
Eupatorium maculatum	spotted Joe-Pye weed	N	●	●	●	●	
Eupatorium purpureum	sweet Joe-Pye weed	N			●	●	●
Eupatorium rugosum	white snakeroot	N	●	●	●	●	●
Festuca arundinacea	Kentucky 31 fescue	P	●	●	●	●	
Festuca obtusa	fescue	N			●		
Fragaria virginiana	wild strawberry	N		●		●	
Galax aphylla	galax	N				●	●
Galium aparine[2]	bedstraw	N		●	●	●	
Galium circaezans	bedstraw	N					●
Galium triflorum	bedstraw	N				●	●
Gaultheria procumbens	wintergreen	N					●
Geranium maculatum	wild geranium	N				●	●
Geum canadense	avens	N			●	●	●
Gnaphalium obtusifolium	rabbit tobacco	N			●		
Goodyera repens	dwarf rattlesnake plantain	N					●
Helianthus microcephalus	sunflower	N		●	●	●	●
Hieracium paniculatum	hawkweed	N		●			●
Hieracium pratense	king devil	N	●	●	●		
Hieracium scabrum	hawkweed	N	●				
Hypericum punctatum	St. John's wort	N				●	
Hystrix patula	bottlebrush grass	N			●		
Impatiens capensis	spotted touch-me-not	N			●		
Impatiens pallida	touch-me-not	N			●	●	
Juncus tenuis	path rush	N		●			
Lactuca biennis	tall blue lettuce	N		●			
Lactuca canadensis	wild lettuce	N		●	●	●	
Lactuca scariola	prickly lettuce	E	●	●	●	●	
Lespedeza cuneata	sericea lespedeza	P	●	●	●	●	
Lobelia spicata	spiked lobelia	N		●		●	
Lotus corniculatus	birdsfoot trefoil	P	●				
Lycopodium flabelliforme	running-pine			●			
Lysimachia quadrifolia	whorled loosestrife	N		●		●	●

[1]N = native, E = exotic, P = planted.
[2]In 1992-93, plants were surveyed in May and August. In 1999, plants were surveyed in August only. By August, *Cardamine hirsuta* and *Galium aparine* had died, and it was impossible to identify individual species of *Viola*.

Table 3. Species observed on reclaimed and forest sites. (cont.)

Latin Name	Common Name	Type[1]	Year Reclaimed 1987-91	1980-87	1972-77	1967-72	Native Hardwood
Medicago sativa	alfalfa	P	●				
Melilotus spp.	sweet clover	P	●				
Monarda clinopodia	basal balm	N				●	
Muhlenbergia tenuiflora	muhly	N				●	●
Oenothera biennis	evening primrose	N	●	●	●	●	
Oxalis stricta	wood sorrel	N		●			●
Panicum spp.	panic grass	N	●	●	●	●	●
Parthenocissus quinquefolia	virginia creeper	N	●	●	●	●	●
Phleum pratense	Timothy	P	●				
Phytolacca americana	pokeweed	N	●	●	●	●	
Poa alsodes	blue grass	N				●	
Poa pratensis	blue grass	P	●				
Polygonum cespitosum	knotweed	E			●	●	
Polystichum acrostichoides	Christmas fern	N	●	●	●	●	●
Potentilla simplex	cinquefoil	N	●	●	●	●	●
Ranunculus spp.	buttercup	N				●	●
Rumex acetosella	sheep sorrel	E		●	●		
Rumex crispus	curly dock	E			●		
Rumex obtusifolius	bitter dock	E			●	●	
Sanicula canadensis	snakeroot	N				●	●
Senecio aureus	golden groundsel	N		●	●	●	
Setaria faberi	foxtail grass	E			●		
Smilacina racemosa	false solomon's-seal	N		●	●	●	●
Smilax rotundifolia	greenbrier	N		●	●	●	●
Solanum americanum	nightshade	N		●	●		
Solidago curtissii	goldenrod	N		●	●	●	●
Solidago flexicaulus	goldenrod	N	●	●	●	●	●
Solidago gigantea	goldenrod	N	●	●	●	●	
Solidago nemoralis	goldenrod	N	●	●	●		
Solidago rugosa	goldenrod	N	●	●	●		
Taenidia integerrima	golden alexander	N					●
Taraxacum officinale	dandelion	E	●	●	●		
Thaspium barbinode	meadow parsnip	N				●	●
Thalictrum dioicum	meadow rue	N				●	●
Thelypteris hexagonoptera	broad-beech fern	N					●
Toxicodendron radicans	poison ivy	N			●	●	●
Trillium grandiflorum	trilium	N					●
Trifolium pratense	red clover	P	●	●			

[1]N = native, E = exotic, P = planted.
[2]In 1992-93, plants were surveyed in May and August. In 1999, plants were surveyed in August only. By August, *Cardamine hirsuta* and *Galium aparine* had died, and it was impossible to identify individual species of *Viola*.

Table 3. Species observed on reclaimed and forest sites. (cont.)

Latin Name	Common Name	Type[1]	Year Reclaimed 1987-91	1980-87	1972-77	1967-72	Native Hardwood
Trifolium repens	white clover	P	●	●			
Tussilago farfara	colt's foot	E	●	●			
Urtica gracilis	stinging nettle	N			●		
Uvularia perfoliata	bellwort	N					●
Uvularia pudica	bellwort	N					●
Veronica serpyllifolia	speedwell	E			●		
Viola blanda	sweet white violet	N		●		●	
Viola canadensis	Canada violet	N				●	
Viola eriocarpa	violet	N					●
Viola hastata	Halberd-leaf violet	N			●	●	●
Viola septemloba	violet	N	●	●	●	●	●
Viola spp.[2]	violet	N		●	●	●	●
SHRUBS AND TREES							
Acer negundo	maple	N				●	
Acer pennsylvanicum	striped maple	N			●	●	●
Acer rubrum	red maple	N	●	●	●	●	●
Acer saccharum	sugar maple	N					●
Aesculus octandra	buckeye	N					●
Amelanchier arborea	serviceberry	N					●
Betula lenta	sweet birch	N	●	●	●	●	●
Buddleja davidii	butterfly bush	E			●		
Carya spp.	hickory	N			●	●	●
Castanea dentata	chestnut	N					●
Cercis canadensis	redbud				●		
Cornus florida	dogwood	N		●	●	●	●
Elaeagnus umbellata	silverberry	N	●	●	●		
Fagus grandifolia	beech	N		●			●
Hydrangea arborescens		N			●	●	●
Juglans nigra	black walnut	N					●
Kalmia latifolia	mountain laurel	N		●			●
Lespedeza bicolor	bicolor lespedeza	N	●	●	●		
Liriodendron tulipifera	tulip poplar	N	●	●	●	●	●
Magnolia acuminata	cucumber tree	N		●	●	●	●
Magnolia fraseri	umbrella tree	N				●	●
Nyssa sylvatica	black gum	N			●	●	●
Oxydendron arboreum	sourwood	N	●	●	●	●	●
Pinus strobus	eastern white pine	P	●	●	●		
Prunus serotina	wild cherry	N	●	●	●	●	●

[1]N = native, E = exotic, P = planted.

[2]In 1992-93, plants were surveyed in May and August. In 1999, plants were surveyed in August only. By August, *Cardamine hirsuta* and *Galium aparine* had died, and it was impossible to identify individual species of *Viola*.

Table 3. Species observed on reclaimed and forest sites. (cont.)

Latin Name	Common Name	Type[1]	Year Reclaimed 1987-91	Year Reclaimed 1980-87	Year Reclaimed 1972-77	Year Reclaimed 1967-72	Native Hardwood
Pyrularia pubera	buffalo nut	N					●
Quercus alba	white oak	N		●	●	●	●
Quercus prinus	chestnut oak	N					●
Quercus rubra	red oak	N	●	●	●	●	●
Rhododendron catawbiense	mountain rosebay	N					●
Rhododendron maximum	rosebay	N		●			●
Rhus glabra	sumac	N		●	●	●	●
Robinia hispida	hairy locust	P	●	●			
Robinia pseudoacacia	black locust	P	●	●	●	●	●
Rosa multiflora	multifloral rose	E		●	●	●	
Rubus allegheniensis	blackberry	N	●	●	●	●	●
Rubus occidentalis	black-cap	N	●	●	●	●	
Salix spp.	willow	N			●	●	
Sambucus canadensis	elderberry	N		●			
Sassafras albidum	sasafras	N	●	●	●	●	●
Tilia americana	basswood	N		●		●	●
Tsuga canadensis	hemlock	N				●	●
Ulmus americana	white elm	N			●	●	●
Vaccinium arboreum	sparkleberry	N					●
Viburnum acerifolium	maple-leaf viburnum	N					●
Vitis aestivalis	wild grape	N		●	●	●	●

[1]N = native, E = exotic, P = planted.

[2]In 1992-93, plants were surveyed in May and August. In 1999, plants were surveyed in August only. By August, *Cardamine hirsuta* and *Galium aparine* had died, and it was impossible to identify individual species of *Viola*.