2009
POWELL RIVER PROJECT RESEARCH AND EDUCATION PROGRAM REPORTS

This publication contains reports of programs supported by the Powell River Project between July 2008 and June 2009.

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REFORESTATION OF MINED LAND FOR BOND RELEASE, PRODUCTIVE LAND USES, AND ENVIRONMENTAL QUALITY

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PROGRESS REPORT (2008-2009)

This report is presented in four parts:

1. An overview of the Powell River Project forestry research program;
2. A technical paper on the growth and productivity of native hardwoods planted in 1992 on mined land on the Powell River Project site (Burger and Fannon, starts on page 7);
3. A technical paper on tree establishment and response (hybrid poplar, white pine, and native hardwoods) to forest practices applied to post-SMCRA mined sites (Fields-Johnson and others, starts on page 20);
4. A description of a new study established in 2007 on the Powell River Project testing the feasibility of growing tree plantations as bio-energy crops for fuel production (Evans and others, starts on page 35).

Dr. Burger in one of the Powell River Project reforestation studies; these trees are now 28 years old.

Powell River Project Forestry Reclamation Research Overview

Forestry is a logical post-mining land use because of its traditional economic importance to the region, and because of the many services it provides the public, such as flood control, water quality, wildlife habitat, carbon sequestration, and aesthetic environments. After the implementation of the SMCRA in 1978, highly-graded mined landscapes covered with agricultural grasses and legumes were common. However, landowners and coal operators throughout the Appalachian coalfields are now commonly reclaiming with trees for forestry using a technique developed by Powell River Project (PRP) researchers. This technique, commonly called the Forestry Reclamation Approach (FRA), is summarized in several new or revised Virginia Cooperative Extension bulletins located at: http://www.cses.vt.edu/PRP/VCE_Pubs.html

The foundation for mined land reforestation practices is based on many Powell River Project forestry research sites in Virginia and adjacent states. The results from these research sites allow us to develop new and revised reforestation guidelines for reclaiming mined land, and they allow us to demonstrate the value of reclaimed forests. Because forestry is a long-term enterprise, we maintain and monitor these field sites over time. The older the research sites become, the more valuable they are, because they show how reclamation treatments will ultimately affect the success and value of the restored forest. In addition to maintaining older experimental sites, we install new experiments each year to fill gaps in our knowledge and address new issues confronting the mining community.

Research Reports

During the year 2008-09 we did research on several existing study sites. Herbaceous ground covers used for erosion control can be very competitive and detrimental to tree survival and growth. This was demonstrated in a six-year study that showed that native hardwoods can grow at three times the rate when ground cover is reduced to 60 to 80% while still controlling erosion. The Virginia Department of Mines, Minerals, and Energy has since changed the ground cover standard for forestry post-mining land uses from 90% to a level needed to control erosion. We summarized the results of this and other long-term studies in Powell River Project Virginia Cooperative Extension publications that are currently available from the Powell River Project website: http://www.ext.vt.edu/pubs/mines/460-124/460-124.html

Part 2 (J. Burger and A. Fannon, starts on page 7) of this report contains the results of a species trial showing that, with time (15 years), valuable native hardwoods such as the oaks and tulip poplar do as well as or better than less valuable species such as commonly-planted sycamore and ash. However, the rates of growth of all species were slower than expected compared to non-mined sites, which means pre-mining capability was not restored on these sites using practices using techniques common in the early 1990s. New FRA procedures should improve post-mining forest productivity.

Part 3 (Fields-Johnson and others, starts on page 20) contains early results from a new and ongoing study designed to demonstrate the benefits of reduced grading and tree-compatible ground covers for native hardwoods and American chestnut hybrids. Reduced grading of topsoil substitutes increases water infiltration, reduces runoff, and improves tree survival and growth.

Tree-compatible ground covers are better for hardwood establishment, and they allow greater recruitment of native plants.

Part 4 (Evans and others, starts on page 35) describes a new study that tests the suitability of reclaimed mined land for growing short rotation (15 years) tree plantations for biomass energy feedstocks. Several fast-growing species planted at two densities are being tested at three locations in Wise County, Virginia.

Ongoing Research Activities

Our ongoing Powell River Project reforestation research program is dedicated to: (1) helping coal operators meet their reclamation requirements; (2) helping landowners maximize the value of their reclaimed mined land; and (3) helping mining communities meet their socio-economic needs. The following ongoing studies are being conducted to meet these goals:

1. *Ground cover control to improve native hardwood establishment*

- This PRP project is in its eighth growing season. The results after five years are featured in a PRP Virginia Cooperative Extension bulletin, "Establishing Ground Cover for Forestry Post-mining Land Uses," VCE No. 460-124. This project is maintained as part of the PRP forestry field tour.

2. *Hardwood establishment field trials*

- This is a large ongoing study with 10 3-acre sites located in three states. The study tests hardwood establishment on a variety of operationally-prepared mined sites in a three-state region. We completed tree, ground cover, and site measurements for 10 continuous years. A preliminary analysis of this project was presented and published at the Annual Meeting of the American Society of Mining and Reclamation in Breckenridge, Colorado, in June, 2005.

  Auch, W. T., J. A. Burger, and D. O. Mitchem. 2005. Hardwood stocking after five years on reclaimed mined land in the Central Appalachians. In: R. I. Barnhisel (ed.). Proc., 22nd Mtg., Amer. Soc. for Mining and Reclamation. June 18-24, 2005, Breckenridge, CO. ASMR, 3234 Montavesta Rd., Lexington, KY.

3. *Growth and productivity of several native hardwoods on reclaimed mined land*

- This species trial was established on three sites at the PRP demonstration area in Wise County, Virginia. The sites had been surfaced-mined for coal in 1990 and reclaimed in 1991 using standard reclamation practices. The purpose of this study was to contrast after 15 years the growth, survival, and overall performance of seven hardwood species. The species groups represented included non-native fuelwood species, upland hardwoods, riparian species, and a valuable but off-site hardwood species. Trees were planted in March, 1992. Northern red oak, white oak, and yellow poplar, all upland native hardwood species, proved to be good choices for general reforestation; however, better reclamation procedures than those used when this study was established (compacted mix of overburden materials with heavy herbaceous ground cover) are needed to restore forest land capability to pre-mining conditions.

- Ms. Amy Gail Fannon, PRP Cooperative Extension Agent, conducted this recent analysis as part of a Virginia Tech undergraduate research course. She presented the work in a national student competition at the Soil Science Society of America Annual Meeting in Houston, Texas. The results of this study were also presented at the annual meeting of the American Society of Mining and Reclamation in June, 2009, in Billings, Montana, and published in the meeting proceedings. This study is featured below as Part 2 of this PRP Progress Report.

  Burger, J. A., and A. G. Fannon. 2009. Forest land capability of reclaimed mined land for seven Appalachian hardwood species. Natl. Mtg., Amer. Soc. for Mining and Reclamation, Billings, MT. *Revitalizing the Environment: Proven Solutions and Innovative Approaches*, May 30-June 5, 2009. R.I. Barnhisel (ed.). ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

4. *White oak response to different mine soil types*

- We continue to monitor an 80-acre native hardwood planting on Rapoca Coal Company land. This cooperative effort among Rapoca, Virginia Tech, and the Virginia Department of Mines, Minerals, and Energy (DMME) serves as a model for the application of Powell River Project reforestation guidelines. Our last report on this study was published in the spring of 2007. We will visit and remeasure the experimental plots on this study site when the trees are 10 years old.

  Showalter, J. M., J. A. Burger, C. E. Zipper, J. M. Galbraith, and P. F. Donovan. 2007. Influence of mine soil properties on white oak seedling growth: A proposed mine soil classification model. *Southern Journal of Applied Forestry* 31(2):99-107.

5. *Reforestation and carbon sequestration by forests and soils on mined land*

- This project was funded by the Appalachian Regional Commission, the Virginia Department of Mines, Minerals and Energy, The Nature Conservancy, the U.S. Department of Energy, and the Powell River Project. The project is directed toward reforestation of compacted mined land reclaimed prior to the implementation of the Forestry Reclamation Approach. It compares survival and growth of three forest types (hybrid poplar plantations, white pine plantations, and mixed native hardwoods) growing on mined land subjected to forest practices (weed control, tillage, and fertilization). This 3x3 factorial experiment is replicated three times in each of three states (Virginia, West Virginia, and Ohio). Results after five years were reported by Chris Fields-Johnson and others at the annual meeting of the American Society for Mining and Reclamation in Richmond, VA, in June, 2008.

  Fields-Johnson, C., C. E. Zipper, and J. A. Burger. 2008. Fourth-year tree response to three levels of silvicultural input on mined lands. Proc., Amer. Soc. of Mining and Reclamation Ann. Mtg., Richmond, VA, June 2008.

- The second objective of this study is to measure the potential of restored forests to sequester large amounts of atmospheric carbon, which is associated with the greenhouse effect and climate change. Much of the elevated level of CO_2 in the atmosphere is attributed to land use change and the burning of coal and other fossil fuels. This project will help determine the benefits of reforesting mined land for sequestering carbon from the atmosphere. Information on this study objective is contained in the following publications:

Amichev, B. Y. 2007. Biogeochemistry of carbon on disturbed forest landscapes. Ph.D. Dissertation. Virginia Polytechnic Institute and State University. 371 p.

Amichev, B., J. A. Burger, and J. A. Rodrigue. 2008. Carbon sequestration by forests and soils on mined land in the Midwestern and Appalachian coalfields of the U.S.. *Forest Ecology and Management*. 256:1949-1959.

6. *Establishing hardwood forests with American chestnut using the Forestry Reclamation Approach: Effects of grading practices and ground cover*

- This project compares the relative success of reforestation established using three different types of ground covers on both compacted and uncompacted mined soils. In the winter of 2008, a native hardwood mix was planted across all sites along with five varieties of American chestnut hybrids. This project is demonstrating the benefits of using the Forestry Reclamation Approach, and it will test the viability of American chestnut hybrids as a species component in reclaimed native forests. This research trial was established with the cooperation of Red River Coal Co. (two study sites) and Paramont Coal Co. (one study site). It was funded by an OSM Applied Science Grant and the Powell River Project.
- An overview of the project and results from initial measurements are featured in Part 3 of this report.

Fields-Johnson, C., C. E. Zipper, J. A. Burger, and D. M. Evans. 2009. First-year response of mixed hardwoods and improved American chestnuts to compaction and hydroseed treatments on mined land. Natl. Mtg., Amer. Soc. of Mining and Reclamation, Billings, MT. *Revitalizing the Environment: Proven Solutions and Innovative Approaches.* May 30-June 5, 2009. R.I. Barnhisel (ed.) ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

7. *Topsoil substitutes and amendments for reforestation*

- The objective of this study is to determine how mine soils weather with time and how they may become more suitable for trees. Important unresolved questions for coal operators are what topsoil substitutes are needed for trees, and whether they are significantly different from those needed for grassland reclamation. The 25-year-old PRP overburden placement study containing plots with different mine soil mixes and organic matter amendments was planted with northern red oaks in spring 2002. Organic amendments included sawdust and four levels of sewage sludge. This project will test the long-term effects of these amendments on soil chemical properties and the growth of red oaks.
- During this proposed project year, we will measure total red oak biomass and nutrient content as affected by the different organic amendments. This study will show if the additional expense of adding organic matter to mine soils is justified based on tree response to these materials.

8. *Bioenergy feedstock production potentials of reclaimed coal mines*

- This project was funded by Alpha Natural Resources and installed with co-PI Carl Zipper in winter 2008 on three sites in Virginia. The purpose is to determine the feasibility of using otherwise unproductive reclaimed mined land for feedstock production for raw materials for conversion to biobased fuels and biobased products. Five years ago, half-acre plots of three planted forest types (hybrid poplar, white pine, and mixed hardwoods) were each treated with three levels of management (weed control, weed control + tillage, and weed control + tillage + fertilizer). Three of the nine replications of this experiment are located on or near the PRP. The outcome of this project will be decision support information for landowners regarding the profitability of reforestation investments, and decision support information for policymakers regarding effects of financial incentives, such as carbon credits, needed to stimulate reforestation by landowners.

- This project is featured as Part 4 of this PRP Progress Report.

Outreach Activities

We conducted a tour of forestry research sites during the Powell River Project field day in September 2008 and supported Arbor Day events conducted by DMME.

We held a field tour for an environmental resource graduate class from Duke University in October 2008.

We participated and gave lectures at a Virginia Professional Engineers in Mining Seminar at the Southwest Virginia Higher Education Center in Abingdon, Virginia.

We co-authored an Appalachian Regional Reforestation Initiative Advisory:

> Burger, J., V. Davis, J. Franklin, C. Zipper, J. Skousen, C. Barton, and P. Angel. 2009. Tree-compatible ground covers for reforestation and erosion control. Appalachian Regional Reforestation Initiative, Forest Reclamation Advisory No. 6. 6 p.

We participated in the 3rd Annual Appalachian Regional Reforestation Conference in Prestonsburg, Kentucky, August 3-6, 2009.

What Are the Benefits of This Reforestation Research?

Our work has provided the foundation for the Forestry Reclamation Approach used by many coal operators in Virginia and adjacent states. It is currently being promoted by the Office of Surface Mining's Appalachian Regional Reforestation Initiative. Economic analyses have shown that the return on mined land reclaimed according to guidelines based on PRP research can be several times higher than on land currently reclaimed to unmanaged land uses. While improving the value of mined land for the landowner, coal operators benefit through more timely and successful recovery of performance bonds, and local communities benefit from land reclamation that improves water quality, reduces flooding potential, is more aesthetically pleasing, and is more valuable for a diversifying economy.

Capability of Reclaimed Mined Land for Supporting Reforestation with Seven Appalachian Hardwood Species[1]

James A. Burger and Amy G. Fannon

Abstract

Reforestation of the Appalachian coalfields with native hardwoods is becoming increasingly popular. However, establishing some hardwood species has been difficult due to the poor quality of many mine soils. The purpose of this study was to contrast after 15 years the growth, survival, and overall performance of seven hardwood species planted on three mine sites in Southwestern Virginia. The seven hardwood species were divided into species groups of a non-native fuelwood species, upland hardwoods, riparian species, and a valuable but off-site hardwood species. Overall tree performance was examined as a function of mine soil chemistry and fertility. Eastern cottonwood grew fastest, and black walnut grew slowest. By age 15, the native hardwoods, white and northern red oaks and yellow poplar, grew better than the American sycamore and white ash riparian species. They also responded to a mine soil fertility gradient while the others did not. The overall forest capability of the post-mined condition of these sites was far less than the pre-mined capability. The average weighted site indices (by extent of all soil series) of 10,000 acres in the vicinity of the mined sites are 82 and 77 for yellow poplar and northern red oak, respectively. Reduction in yellow poplar site index between the pre- and post-mined capability was 26 feet, and the difference for red oak was 15 feet. Northern red oak, white oak, and yellow poplar, all upland native commercial hardwood species, would be better choices for general reforestation than riparian species; however, better reclamation procedures than those used when this study was established (compacted mix of overburden materials with heavy herbaceous ground cover) are needed to restore forest land capability to pre-mining conditions.

Introduction

Prior to the introduction of the Surface Mining Control and Reclamation Act (SMCRA), many mined sites in the Appalachian and Midwestern coalfields were planted with native hardwood species (Ashby 1996, Rodrigue et al. 2002). Pre-law sites were normally loose overburden with variable soil properties, but they usually provided a good growing medium for trees (Ashby 1998, Rodrigue and Burger 2004). Once the SMCRA was passed, reclamation of mined sites was mandated and mined sites had to be returned to approximate original contour (SMCRA 1977). In addition, the law required that the land be returned to its original use and land capability (Section 515(b)(2), SMCRA 1977). To achieve these mandates, grading of slopes became a common practice, and soil compaction, runoff, and erosion became major issues (Burger 1999). Erosion control groundcovers greatly competed with trees for soil resources, and compaction of the graded land caused rooting problems (Andersen et al. 1989, Burger 1999). These limitations continue to impede reforestation in the Appalachian coalfields, and researchers and practitioners are seeking solutions to the problem of repeated reforestation failures to include selection of the best tree species for mined land conditions.

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[1] Presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, *Revitalizing the Environment: Proven Solutions and Innovative Approaches,* May 30-June 5, 2009. R.I. Barnhisel (ed.). ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

Several studies have been conducted using various tree species for surface mine reclamation. Many aspects of species performance, including survival, rate of growth, and economic feasibility, have been examined to develop options for landowners and companies for restoring native forests and making their land as productive as possible (Plass and Powell 1988). Eastern white pine (*Pinus strobus* L.), loblolly pine (*P. taeda* L.), and Virginia pine (*P. virginiana* Mill.) are conifer species that can grow as well on mine soils as on undisturbed sites when mine soil conditions are properly managed (Torbert et al. 2000). However, the natural vegetation of the Appalachian region is primarily hardwoods. In recent years, several researchers have recommended reforestation using native hardwoods and have reviewed the practices that would ensure their success (Ashby 1999, Burger et al. 2008).

Rodrigue et al. (2002) compared hardwood growth on reclaimed sites to that on undisturbed sites and found similar production rates when mine soils were of good quality. Ashby (1996) also reported good growth for black walnut, oaks, and several other native hardwood species on pre-law overburden in the Midwest, but post-law reforestation was largely unsuccessful (Ashby, 1996). Groninger et al. (2006), in a survey of reforestation success at 22 post-law mines in Indiana, found that most sites were too compacted to support native hardwoods. Black locust and green ash were the dominant species surviving, and average oak site index was only 30 feet at age 50 versus 60 to 70, which is common on medium quality undisturbed sites in the region. This shows that mined site quality greatly limits forest productivity and the tree species that can survive on mined sites reclaimed since the implementation of the SMCRA. Similar observations on the adverse effects of post-law reclamation on tree survival and productivity were made in the Appalachian region (Torbert et al. 1985, Kost et al. 1998). On the other hand, in a recent study in southwest Virginia, Burger et al. (2008) reported excellent survival and growth for several hardwood species, including white ash, yellow poplar, red oak, and white oak, on good quality mine soils where competing groundcover vegetation was controlled using herbicides. This study suggests great promise for native hardwoods; however, there is limited research on the soil factors limiting the survival and growth of specific species. In 1992, a tree species trial consisting of seven species (yellow poplar, eastern cottonwood, northern red oak, white ash, black walnut, American sycamore, and white oak) was established on a recently reclaimed surface mine in Wise County, Virginia, to compare survival, growth, and overall tree performance, and to determine relative tree growth as a function of mine soil chemistry and fertility 15 years after establishment.

Methods and Procedures

The species trial was established on three different Wise County, Virginia, sites that had been surfaced-mined for coal in 1990 and reclaimed in 1991 using standard reclamation practices. The mined sites were graded and tracked and sown with erosion control ground covers that included tall fescue, orchardgrass, and serecia lespedeza. Mine soils consisted of a mix of sandstone and siltstone overburden materials that were only moderately compacted on steep slopes. Slopes ranged from 39% to 50%, and slope aspect varied from northwest to southeast. Trees were planted in March, 1992. Seven species, including northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), white ash (*Fraxinus americana* L.), black walnut (*Juglans nigra* L.), cottonwood (*Populus deltoides* Bartram ex Marsh.), American sycamore (*Platanus occidentalis* L.), and yellow poplar (*Liriodendron tulipifera* L.) (same as tulip poplar), were planted as 2-0 seedlings. Seedlings were obtained form the Virginia Department of Forestry tree nursery. The trees were planted at 14 x 14-foot spacing in 3 rows per species with 8 trees per row to create single-species plots of 24 trees. The experimental study was a randomized complete block design with three blocks (replications) on three different mined sites (yellow poplar was planted on blocks 1 and 3 only). The block design accounted for possible variation in tree growth due to site differences. In order to simulate operational conditions, no maintenance or stand improvement operations were conducted on the sites. The agricultural erosion control grasses and legumes sown prior to tree planting were dense and competitive during the entire study period. They included tall fescue (*Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.), redtop (*Agrostis gigantean* Roth), perennial ryegrass (*Lolium perenne* L.), red clover (*Trifolium pretense* L.), and serecia lespedeza (*Lespedeza cuneata* (Dum.-Cours.) G. Don). They provided nearly 100% ground cover and were 2 to 3 feet tall on all three sites; they began to lose some vigor after 10 to 12 years when the trees closed canopy.

Tree height was measured in the early spring of 2007 using a clinometer or meter pole, depending on height, and diameter was measured at breast height using a diameter tape. Survival rate was calculated by comparing surviving trees with the number planted in 1992. Differences in tree survival, height, and diameter among species and species groups were analyzed using ANOVA (SAS, 2001). For evaluation and analysis purposes, species were grouped by site type and potential commercial value to include the following groups: (1) non-native fuelwood (eastern cottonwood), (2) high-value hardwood requiring fertile sites (black walnut), (3) medium-value hardwoods adapted to upland, average-quality sites (northern red oak, white oak, yellow poplar), and (4) low-value hardwoods found in bottomlands or riparian environments (American sycamore and white ash). Analysis of variance among groups was done with SAS Proc GLM (SAS 2001), which accommodated unequal sample sizes.

Three soil subsamples were taken randomly within each species plot and composited. Soils were analyzed for nitrogen and carbon content using a CRN analyzer (Vario MAX, Elementar MAX Instruction Manual 2000). Plant-available macro- and micronutrients were determined using Mehlich I extraction and ICP spectroscopy (SpectroFlame Modula Tabletop ICP, Spectro Analytical Instruments Inc., Fitchburg, MA). Soil reaction (pH) was measured in a 2:1 water:soil solution, and cation exchange capacity (CEC) was calculated by summing the charge contributed by exchangeable Ca, Mg, K, and Na concentrations. Correlations between volume index (d^2h) and soil fertility variables were tested using correlation statistical procedures in JMP statistics software (SAS 2001).

Results and Discussion

Tree Survival

Species 15-year survival rates ranged from 54.2% (yellow poplar) to 76.4% (eastern cottonwood). Overall, all species survived equally well, as there were no significant differences in survival among species or between species groups (Fig. 1). Eastern cottonwood was the only species that exceeded the 70% survival rate, which is a target level used to judge successful reforestation (Burger et al. 2008). Yellow poplar survival was lowest, which was consistent with reports by Ashby (1996) and Cleveland and Kjelgren (1994) showing that yellow poplar survival is variable and site-specific. Survival of the remaining species averaged around 60%, which is a bit lower than expected under average conditions of site and seedling quality and season-to-season climatic variation.

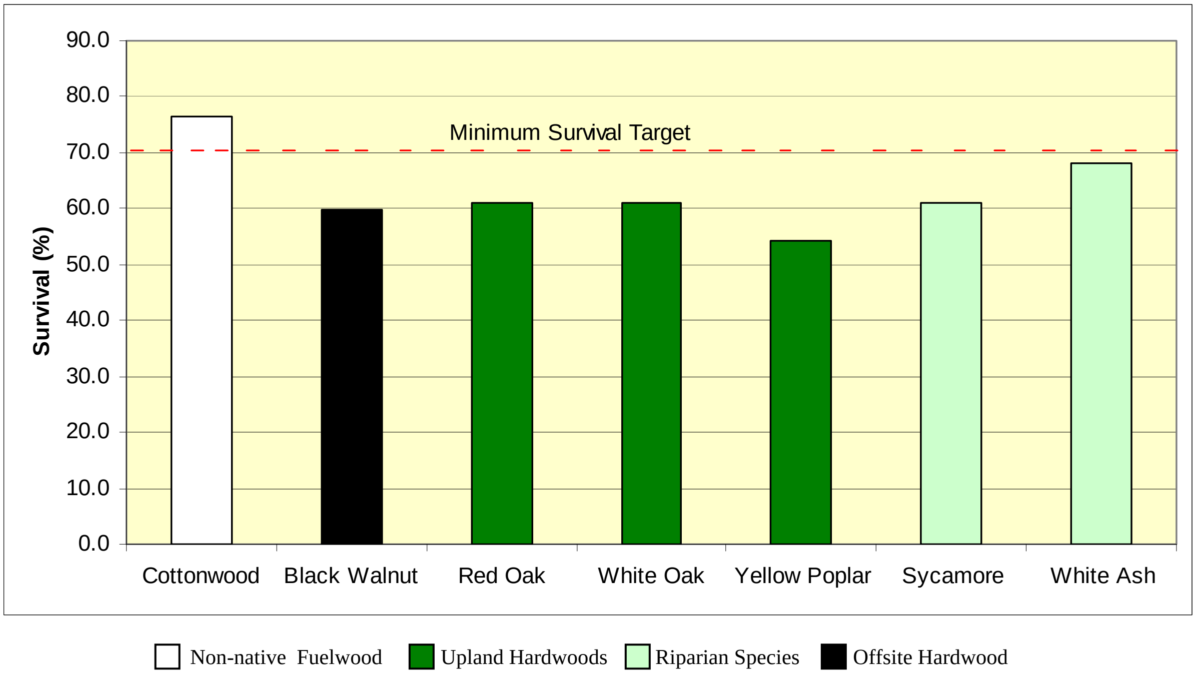

Figure 1. Fifteen-year survival rate (%) of seven hardwood species and groups of upland hardwoods, offsite hardwood, non-native fuelwood, and riparian hardwood species on a species trial in southwestern Virginia.

Tree Growth

Relative tree growth was evaluated using tree height, diameter, and a tree volume index estimated as the product of the height and the square of the diameter (d^2h). Tree height and diameter varied partly as a function of species type, and partly as a function of species response to the mine soil environment. Eastern cottonwood height of 42.01 ft (Fig. 2A) and diameter of 7.45 in (Fig. 2B) exceeded all other species because it is a fast-growing, early-successional species. It grew at a poor rate (SI = 60, base age 25 years) relative to its performance on undisturbed, bottomland sites (SI = 70 or more, base age 25 years) (Meyers and Buchman 1984). Cottonwood is commonly found and does best on moist alluvial sites along streams and across broad river bottoms. Despite its relatively poor growth, cottonwood may be a good candidate for fuelwood plantations if and when such enterprises become viable at a local level. It is native to Virginia, but not common in the Appalachian region.

Black walnut survived well, but it grew very poorly (Fig. 2ABC). This was consistent with other species trials on Appalachian mined sites (Torbert et al. 1985, Skousen et al. 2009). Black walnut has been used effectively on midwestern mined sites (Ashby 1996), but it is unlikely that it will be useful as a valuable timber tree on mined sites in the Appalachians. It is native to the Appalachians, but on upland sites, it seldom has the required form or growth rate to be a commercially viable timber tree, even on undisturbed sites.

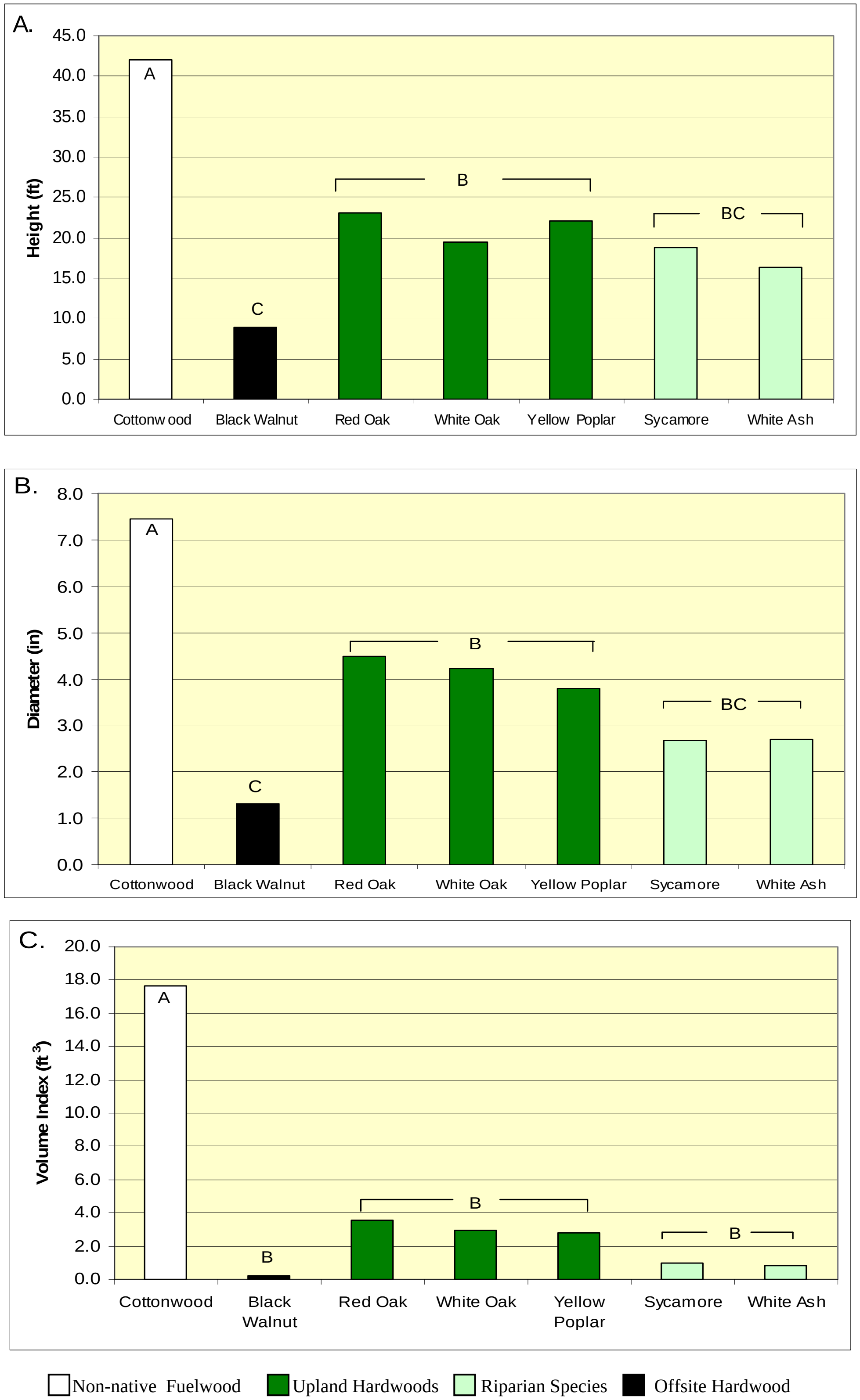

Figure 2. Height (A), diameter (B), and volume index (C) of seven species in Wise County, Virginia, with corresponding species groupings (different letters among species or species groups indicate significant differences (P < 0.1)).

The average height of the upland hardwoods (northern red oak, white oak, and yellow poplar) was around 20 ft, and the riparian species (white ash and American sycamore) had an average height around 17 ft (Fig. 2A). The average diameter was 4.0 in for the upland species and 2.8 in for the riparian species (Fig. 2B). Upland hardwoods and riparian species both showed good growth (Fig. 2C), but the upland species appeared to be growing slightly better, although the volume index was not significantly different. White ash and American sycamore have long been considered reclamation species because of their good survival and good early growth, despite the fact that they are largely riparian species and functionally off-site on an upland mined site environment. As early-successional pioneer species, they naturally grow quickly when seeded or planted, and we speculate that they do well on mined sites because they can tolerate poorly drained and poorly aerated soil conditions, which are characteristic of compacted mine soils. Our results show, however, that the upland species will eventually outgrow the off-site riparian species as they become established and reach stand closure. This is an important finding because it shows that the valuable oaks and tulip poplar can do well provided they are planted on reasonably productive mined sites and protected from excessive ground cover vegetation. With time, they have the potential to develop into a valuable forest stand and are better suited for the upland environment of most mined sites.

Soil Fertility

Soil compaction from heavy grading of mine soil surfaces may be the greatest impediment to the success of native hardwoods, but as mine operators change their practices to accommodate forestry post-mining land uses with deeper and looser mine soils, soil fertility may become the factor controlling or limiting hardwood growth (Bendfeldt et al. 2001). Among the three replicate sites, soil chemistry and fertility varied. Site 1, especially, had higher pH, Ca, CEC, and base saturation (BS) levels, but N and P also varied among sites (Table 1).

Eastern cottonwood volume was negatively correlated with N, P, and C, which is counter-intuitive; therefore, some other factor such as inadequate soil water might have been responsible for its overall poor growth compared to its potential on moist alluvial sites where it is commonly found (Table 2). The growth of the riparian species (white ash and American sycamore) was positively correlated with pH and Ca levels, suggesting that these species prefer less acidic soil environments. The growth of the upland hardwoods (red and white oaks and tulip poplar) was positively correlated with pH, Ca, P, CEC, BS, and soluble salts, showing a clear affinity for more fertile sites. The poor growth of black walnut might have been related to inadequate N and P, as suggested by the positive correlations, but inadequate soil water probably played a greater role given its high soil water requirements.

Table 1. Soil properties of three surface mine sites in southwestern Virginia by species plots.

Species	pH	N	C	OM	P	K	Ca	Mg	Soluble Salts	CEC	Base Sat
		(%)	(%)	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(ppm)	(meq/ 100g)	(%)
Site 1											
Red oak	6.64	0.197	3.96	5.2	33	55	2066	203	128	12.2	99.6
Yellow poplar	7.18	0.219	3.52	5.5	22	66	1994	232	115	12.0	100
Black walnut	6.85	0.169	2.71	4.3	19	63	1370	230	102	8.9	99.4
White oak	7.19	0.207	3.30	4.9	16	66	2028	233	141	12.2	100
Sycamore	7.02	0.246	3.81	5.8	30	62	1604	243	115	10.2	100
White ash	7.02	0.226	4.07	6.3	23	72	1872	231	115	11.4	100
Cottonwood	7.04	0.218	3.59	5.9	17	73	1796	257	115	11.2	100
Mean	**6.99**	0.212	3.57	5.4	23	65	**1818**	233	119	**11.2**	99.9
Site 2											
Red oak	5.54	0.196	3.20	5.3	14	80	704	219	77	8.2	66.9
Black walnut	6.10	0.223	3.75	5.4	24	94	959	288	90	8.5	86.8
White oak	6.13	0.250	4.20	8.2	19	77	1090	285	102	9.4	84.3
Sycamore	6.10	0.240	4.08	6.7	20	85	1114	297	102	9.3	88.5
White ash	5.63	0.167	2.84	4.2	14	85	694	220	77	7.3	75.5
Cottonwood	6.12	0.208	3.42	5.3	18	122	1049	275	102	8.9	87.4
Mean	**5.94**	0.214	3.58	5.9	18	91	**935**	264	92	**8.6**	81.6
Site 3											
Red oak	5.55	0.145	2.37	4.0	7	66	573	116	51	5.8	69.1
Yellow poplar	5.10	0.122	1.91	3.8	3	66	374	82	51	6.6	40.8
Black walnut	5.14	0.101	1.69	3.4	2	61	406	86	38	6.9	42.1
White oak	5.66	0.171	2.91	4.8	8	107	867	184	64	7.9	77.4
Sycamore	5.66	0.209	3.32	6.4	7	89	861	179	64	8.5	70.6
White ash	5.60	0.180	2.62	5.4	5	81	838	154	64	7.3	77.3
Cottonwood	5.76	0.159	2.42	5.2	6	138	860	159	77	7.6	78.8
Mean	**5.49**	0.155	2.46	4.7	5	87	**683**	137	58	**7.2**	65.2

Table 2. Significant correlations of species group volume index as a function of soil chemical and fertility properties (Proc Corr, SAS 2001).

Species Groups	Soil Property	Correlation Coefficient	Probability Level
Non-native (cottonwood)	N%	-.9967	.0520
	C%	-.9983	.0366
	P	-.9884	.0971
Riparian Hardwoods (white ash & sycamore)	pH	.8037	.0540
	K	-.8105	.0505
	Ca	.7795	.0675
Upland Hardwoods (red oak, white oak, yellow poplar)	pH	.8230	.0121
	P	.6874	.0596
	Ca	.8973	.0025
	CEC	.8104	.0147
	Base Sat	.7980	.0176
	Soluble Salts	.7816	.0220
Offsite (black walnut)	P	.8866	.0524
	Mg	.9998	.0117
	N%	.9878	.0997

Volume growth rates of the upland species (red and white oaks and tulip poplar) and the native riparian species (ash and sycamore) were regressed (simple linear regression) with indicators of soil fertility including pH, CEC, and Ca (Figs. 3, 4, and 5). As these soil properties increased in value, growth of the upland species increased considerably. Tree volume increased threefold across a pH gradient ranging from 5.5 to 7, a CEC gradient ranging from 6 to 12 $cmol^+ kg^{-1}$, and a Ca gradient ranging from 500 to 2000 mg kg^{-1}. These soil properties are related to one another, so it is not possible to discern which is most influencing tree growth. However, they are all related to soil acidity and nutrient availability and collectively suggest that increasing soil fertility dramatically improved the growth of these three species. The pH, CEC, and Ca gradients had little or no effect on the native riparian species. These species have approximately the same nutrient requirements as the upland species and are known to thrive at near-neutral pH and high fertility conditions. Their inability to respond to increasing fertility is probably due to stress associated with limited soil water on these upland sites, exacerbated by the constant competition for water by the agricultural grasses sown for erosion control.

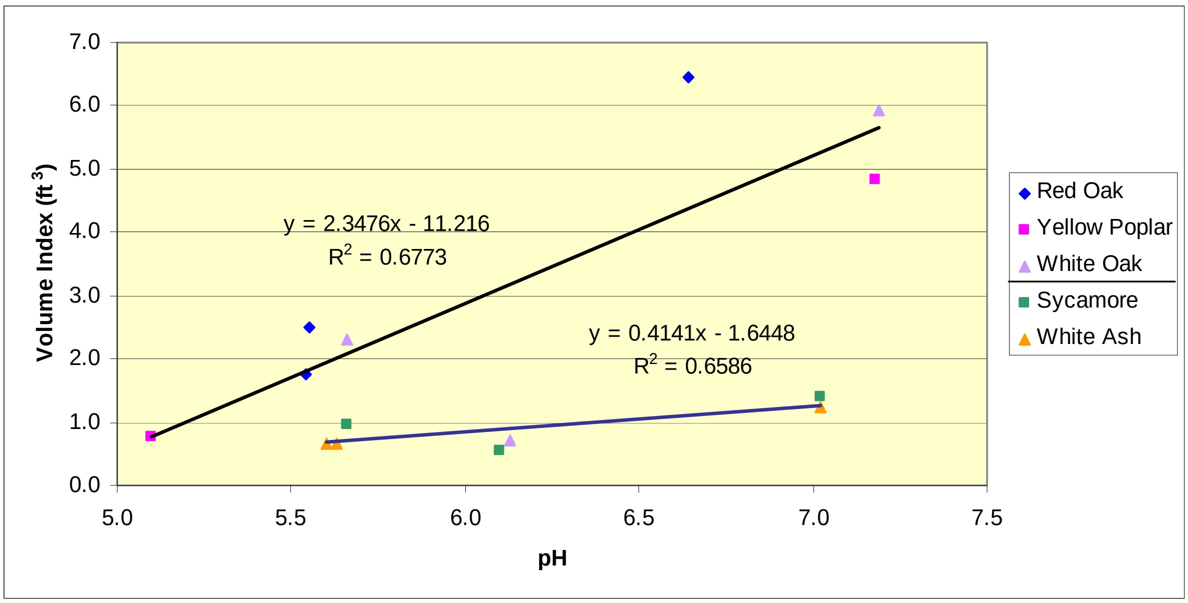

Figure 3. Volume index of upland hardwoods (red oak, yellow poplar, and white oak) and riparian species (sycamore and white ash) as a function of soil pH.

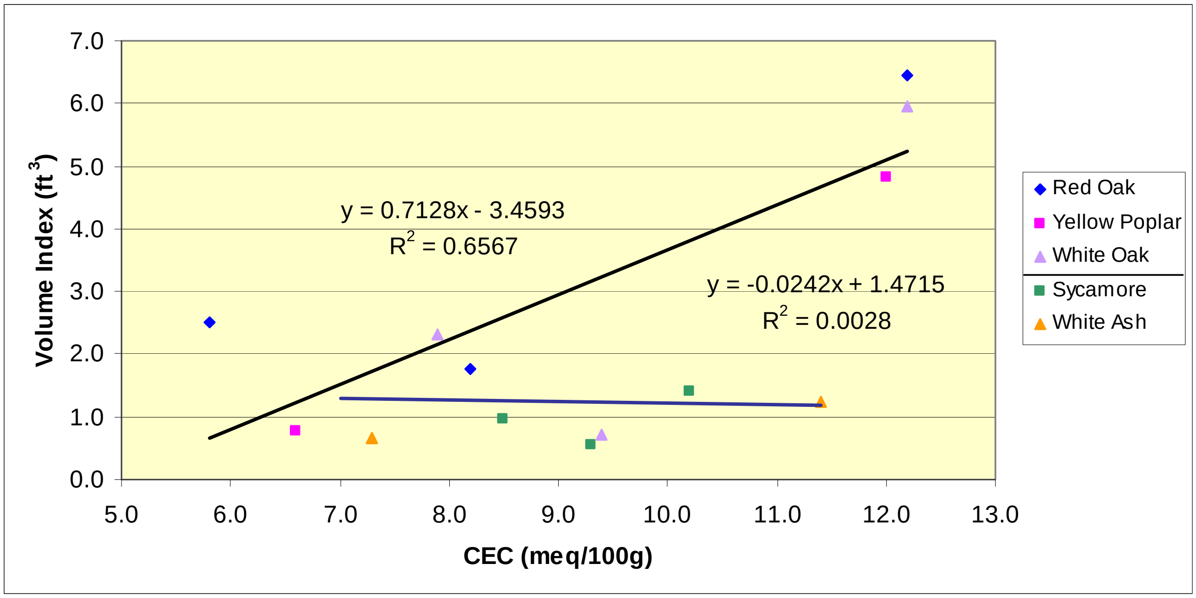

Figure 4. Volume index of upland hardwoods (red oak, yellow poplar, and white oak) and riparian species (sycamore and white ash) as a function of soil CEC.

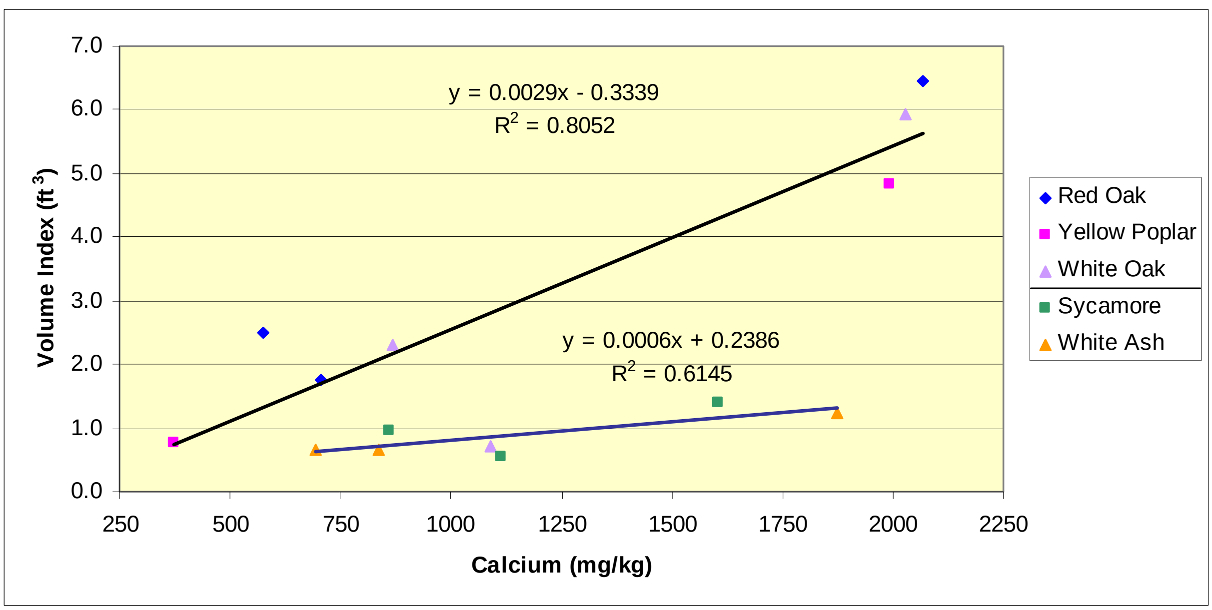

Figure 5. Volume index of upland hardwoods (red oak, yellow poplar, and white oak) and riparian species (sycamore and white ash) as a function of soil Ca concentration.

These results demonstrate that over the long run, the native upland species were more suited to the mined land conditions than the ash and sycamore, despite the riparian species' tendency to grow faster during the first 5 years after planting. The upland species are far more valuable as timber crops than the riparian species. Except for possible infestation of the oaks by the gypsy moth at some future date, these upland species are relatively low-risk choices for reclamation. White ash has value, but it is threatened by the imminent invasion of the emerald ash borer, a serious pest killing the ash in the northeastern and midwestern U.S. Coal operators and reclamation specialists like planting ash and sycamore because they survive well and have a fast early growth habit. This study shows that the upland species survive equally well and grow better over the long run, and landowners will benefit from their higher value.

Site Productivity

The average productivity of the reclaimed mined sites was site index 56 ft (age 50) for both tulip poplar and red oak (Fig. 6) (Carmean et al. 1989). Site index (SI) is the most common way of estimating the capability or yield potential of forest land. It refers to the height of dominant or codominant trees in a forest canopy at a designated age, usually age 50 for eastern hardwoods and age 25 for conifers and other fast-growing trees such as eastern cottonwood (Avery and Burkhart 2002). For example, on good sites, red oak will attain a height of 80 feet in 50 years (SI = 80), and on poor sites, a height of 50 feet in 50 years (SI = 50). Site index is species-specific; some trees grow taller than others on the same site. Therefore, yellow poplar would have a SI of 85 on the good site, but may not have a higher SI than red oak on poor sites because it is more site-sensitive. Of course, tree height is closely correlated with wood yield of forest land, so it is equivalent to using bushels of corn per acre to measure cropland capability.

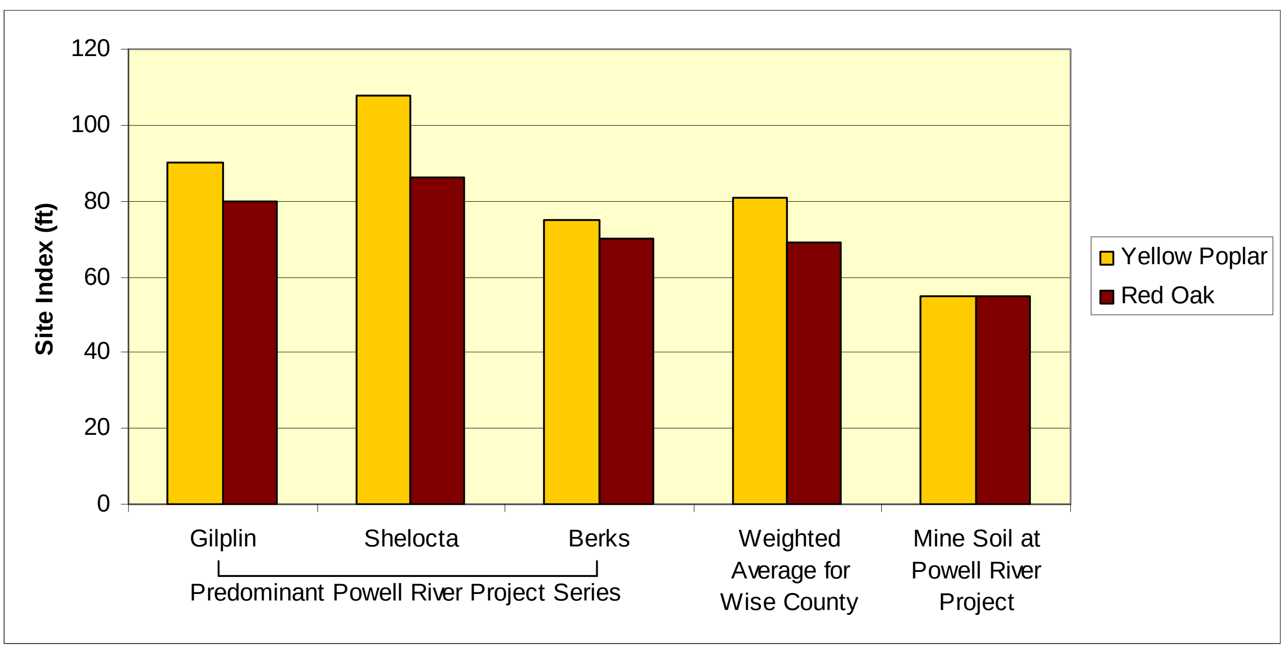

Figure 6. Forest site indices of predominant soil series in the study area, a weighted average of site index for the Jefferson National Forest in Wise County, Virginia, and yellow poplar and red oak site indices of reclaimed mine soils on the Powell River Project Demonstration Area.

The data in Figure 6 show that the forest capability of the post-mining condition is considerably less than that of the predominant soil series that existed prior to mining. The tulip poplar site indices for the Gilpin, Shelocta, and Berks soils are 90, 107, and 77, respectively, compared to SI 56 for the reclaimed sites. These soil series are derived from shales, siltstones, and fine grained sandstone and occur throughout the Appalachian coalfields. The average weighted (by extent of all soil series) site index of 10,000 acres in the vicinity of the mined sites is 82. Therefore, the difference in tulip poplar SI between the pre- and post-mined capability is 26 feet, and the difference for red oak is 15 feet.

The difference in capability or forest yield between the pre- and post-mined conditions is greater than the SI or tree height data suggest. As trees increase in height, the diameter of the stems, or tree trunks, increases roughly exponentially (d^2h) (Avery and Burkhart 2005). Therefore, the wood yield and value are proportionately greater for large trees (high SI) than for small trees (low SI). Extrapolating from data by Fox (2002), the oak sawtimber volume of a mature fully-stocked oak forest on these pre-mined sites (SI = 77) would be approximately 12,000 board feet per acre (bf/ac), and about 4,000 bf/ac after mining (SI = 56). Because the wood in large trees on good sites is worth more than the wood in smaller trees on poor sites, the stumpage value is higher for the trees on the good sites ($363 versus $266 based on 2002 prices as reported by Fox). Therefore, the timber capability value for the pre-mined sites is $4,392/ac compared to $1,064/ac for the post-mined sites, a fourfold reduction in capability. Nonetheless, the upland species (red and white oaks and tulip poplar) used in this study will eventually be far more valuable than the white ash, American sycamore, eastern cottonwood, and black walnut, despite the fourfold reduction in post-mining forest land capability. The study shows that the more valuable upland species should be planted on most mined sites rather than the commonly-planted riparian species because the upland species eventually grow better and are more valuable. Although overall growth rates were lower than average rates expected for pre-mining conditions, reduced compaction and the use of tree-compatible ground covers would likely improve the performance of these upland species on reclaimed mined land. A forestry reclamation approach that includes best practices for restoring native hardwoods on mined land is outlined by Burger and Zipper (2009) and Burger et al. (2005).

Conclusions

Reforestation of mined land is becoming more commonplace as landowners become aware that reforesting their previously forested land is the most economically-viable post-mining land use (Probert 1999). Researchers and coal operators are also finding that reclamation procedures geared for reforestation are less expensive than traditional reclamation procedures used for establishing grassland (Burger and Zipper 2009). This renewed interest in mined land reforestation prompted us to study the capability of mine soils for tree species that provide the best value for landowners while restoring native forest diversity for other ecosystem values.

The results of this 15-year-old species trial on traditionally-reclaimed mined land (compacted with agricultural grasses and legumes used as ground cover) shows that native upland tree species, including red and white oaks and yellow poplar, outperformed white ash and American sycamore riparian species that have been preferred reclamation trees because of their fast early growth. With time, the drought-tolerant upland species, which happen to be far more commercially valuable, grew better and have good potential as components in mixed native hardwood stands.

The overall forest capability of the post-mined condition of these sites was far less than the pre-mined capability. The average weighted (by extent of all soil series) site indices of 10,000 acres in the vicinity of the mined sites are 82 and 77 for yellow poplar and red oak, respectively. Therefore, the difference in yellow poplar SI between pre- and post-mined capability was 26 feet, and the difference for red oak was 15 feet. The timber capability value for the pre-mined sites was $4,392/ac, compared to $1,064/ac for the post-mined sites, a fourfold reduction in capability. Nonetheless, as these trees mature, the upland species (red and white oaks and yellow poplar) will be far more valuable than the ash, sycamore, cottonwood, and black walnut, despite the fourfold reduction in post-mining forest land capability. As coal operators fully employ the forestry reclamation practices advocated by the Office of Surface Mining's Appalachian Regional Reforestation Initiative (Burger et al., 2005), pre-mining forest capability should be restored as the SMCRA requires.

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First-Year Response of Mixed Hardwoods and Improved American Chestnuts to Compaction and Hydroseed Treatments on Reclaimed Mine Land[1]

C. Fields-Johnson, C. E. Zipper, J. A. Burger, and D. M. Evans

Abstract

There is increasing interest in the restoration of native Appalachian hardwood forests using the Forestry Reclamation Approach (FRA) on sites that are being reclaimed following surface mining for coal. Additionally, much interest has developed in the deployment of American chestnut trees that have been improved through breeding to have both blight resistance and timber tree stature. Including chestnuts in planting mixes for the FRA is one potential method to efficiently re-introduce them in the central Appalachian region, but the viability of this method needs to be assessed. There are further questions regarding how choices of herbaceous vegetation and grading practices affect tree survival and growth and plant succession on reforested mine sites. A new experiment combining components of the FRA with plantings of American chestnut trees was begun in the spring of 2008 on active coal-mining sites in Virginia with the goal of directly assessing the effects of grading and groundcover treatments on reforestation success, using a planting mix that includes American chestnut. On each of the three sites, half of the experimental area was smooth-graded and tracked-in as per common reclamation practice, and the other half was loose-graded as recommended using the FRA. Within each grading treatment plot, one-third of the area was hydroseeded with a conventional herbaceous vegetation mix, one-third was seeded with a tree-compatible herbaceous mix, and one-third was seeded with annual ryegrass. All treatments were planted with a mix of native hardwood trees. The loose-graded sections were also planted with six genotypes of chestnut, including pure American, Chinese, and American x Chinese crosses. Tree survival and growth, groundcover, and native plant volunteers were measured. After one growing season, tree survival was not affected by any of the experimental treatments. The tree-compatible mix and the conventional mix provided significantly more ground cover by August than did the annual rye. Loose grading reduced soil loss compared to smooth grading. Chestnut trees grown from planted nuts were competitive with other species' survival rates.

Introduction

Successful rehabilitation of mined land is necessary in order to prevent mining from degrading the land base of agricultural and forest systems and the ecological services those systems provide. Land base degradation makes no sense in a world of growing human populations and ongoing desire for sustainable economic development. Coal surface mining in Appalachia will go on as long as it is economically and politically feasible, and there is a logical imperative to employ the best land reclamation and rehabilitation practices in the course of inevitable mining operations.

[1] Presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches.*** May 30-June 5, 2009. R.I. Barnhisel (ed.) ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

Background

Since 1980, shortly after the implementation of the SMCRA, researchers with the Powell River Project at Virginia Tech have been developing reforestation practices called the Forestry Reclamation Approach (FRA) (Burger and Zipper 2002). A cooperative effort called the Appalachian Regional Reforestation Initiative (ARRI) was formed in December of 2005 to specifically advocate the use of the FRA for proper restoration of native forests on sites reclaimed following coal mining in the eastern United States. ARRI goals are to encourage planting of more hardwood trees of high value, using methods that increase the planted trees' survival and growth, and to accelerate forest succession to establish forest habitat (Angel et al. 2005).

The Forestry Reclamation Approach is a mine reclamation method that has been developed through scientific research and field experience to achieve these goals and has been approved by regulatory agencies. The FRA can be implemented by coal mining operators more cost-effectively than traditional mine reforestation approaches, which entail heavy grading and vigorous herbaceous vegetation (Burger and Zipper 2002). The FRA is intended to restore ecosystem services such as clean water, carbon sequestration, clean air, and habitat for wildlife and other plants (Angel et al. 2005).

The ARRI is needed in order to correct key problems created by common reclamation practices under the SMCRA that hindered restoration of productive native forests on mined land. These key problems, meant to stabilize land and prevent erosion, were the compaction of soil during re-grading and the planting of aggressive herbaceous vegetation (Angel et al. 2005). The ARRI seeks to inform operators of the steps necessary to avoid and/or mitigate these key problems and demonstrate the value of native forests. The FRA can achieve the requirement in the SMCRA that land be restored to equal or higher use and productivity (Angel et al. 2005). Five steps summarize the FRA process (Burger et al. 2005):

1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone, and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in Step 1 to create a non-compacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees—early succession species for wildlife and soil stability, and commercially valuable crop trees.
5. Use proper tree planting techniques.

The FRA is intended to allow full compliance with federal regulations through cost-effective practices by mine operators while successfully re-establishing native forest species. The FRA can be modified to accommodate other forest land uses such as woody biomass production, fruit orchards, or ornamentals (Burger et al. 2005).

Low-compaction grading helps planters plant trees correctly, allows rain water to infiltrate the soil rather than moving off in erosive surface flow, allows the soil to hold more water and air that supports tree growth and soil life, and allows roots to grow more freely. Low-compaction grading is also less expensive than traditional grading practices because it involves fewer machine hours to make fewer grading passes over reclaimed sites (Sweigard et al. 2007).

Tree survival and growth are generally higher on loose-graded mine sites than on compacted and tracked-in mine sites. Numerous experimental studies have demonstrated that high soil bulk density, which occurs as a result of excessive soil compaction, has a negative effect on tree growth (Jones et al. 2005, Rodrigue and Burger 2004, Andrews et al. 1998, Torbert and Burger 2000, Torbert and Burger 1990).

Reforestation practices are meant to accelerate natural forest succession with direct tree planting. Simultaneously, grasses, legumes, nurse shrubs, nurse trees, and crop trees are established, and these perform their functions of stabilizing land and accumulating nutrients before yielding to other plant types in the process of succession. Under Virginia regulations implementing SMCRA (4VAC25-130-816.116. Revegetation; standards for success), lands reclaimed to support a commercial forest post-mining land use are required to have at least 400 trees/ac of commercial value and at least 40 additional trees/ac of wildlife value at bond release. Non-commercial forests have a 400-tree/ac stocking requirement, but it is not required that the trees used be of commercial value. Given the normal survival rates achieved when appropriate reclamation practices are used, planting 550 crop trees and 60 to 100 wildlife or nurse trees per acre can usually achieve these stocking requirements (Burger and Zipper 2002).

Natural mountain forest landscapes in the Appalachians are uneven with many rocks, boulders and rough, loose soils. That is a very different environment than the smooth-graded, compacted soils sought by reclamation specialists in the past. The SMCRA only requires compaction where it is needed to ensure stability. There is, therefore, little reason to compact reclaimed sites when stability can be otherwise achieved, especially on areas that are level or have only gentle, short slopes.

Species of forage often used for hayland/pasture are not compatible with trees. These species include Kentucky-31 tall fescue, red clover, and sweet clover. Legumes can provide up to 50 lbs/ac/yr of nitrogen to the soil in conjunction with *Rhizobium* bacteria. Favorable legumes include birdsfoot trefoil (*Lotus corniculatus*) and white or ladino clover (*Trifolium repens*). Favorable annual grasses include foxtail millet (*Setaria italica*) and annual ryegrass (*Lolium multiflorum* Lam.). Favorable perennial grasses include perennial ryegrass (*Lolium perenne*), timothy *(Phleum pratense)* and, for steep slopes, orchardgrass (*Dactylis glomerata*). Weeping lovegrass (*Eragrostis curvla*) is a tall grass that is useful on acid sites at low seeding rates (Burger and Zipper 2002). Favorable groundcovers are low-growing to allow light to reach young trees growing among them and do not create a continuous sod, which would compete vigorously with trees for water resources.

Goal and Objectives

The goal of this study is to assess the effects of grading and herbaceous vegetation practices on the survival and growth of native hardwoods, including the American chestnut, when these practices are deployed on an active mining operation at a full operational scale.

We tested the following hypotheses:

1. Increased levels of grading and tracking by mining equipment:
   - depress the growth and survival of planted native hardwood trees;
   - accelerate soil loss.

2. Increased levels of herbaceous groundcover:
   - depress the growth and survival of planted native hardwood trees;
   - have a negative effect on recruitment of native vegetation.

Finding or failing to find experimental support for these hypotheses will test some of the assumptions of the FRA and provide insight into how it might be improved in theory and in practice.

Methods and Materials

Overview of Treatments and Design

Three experimental sites (blocks) were established by cooperating mining firms on active mining sites in southwestern Virginia (Fig. 1). The sites shared similar topographical characteristics with steep, long slopes. Blocks 1 and 2 were near Norton, Virginia (Fig. 2) and Block 3 was near Carbo, Virginia (Fig. 3). Block 1 is also referred to as the “Red River Coal” site (Fig. 4), Block 2 as the “Powell River Project” site (Fig. 5) and Block 3 as the “Carrie Ridge” site (Fig. 6). At each site, two grading treatments and three vegetation treatments were installed as a 2x3 factorial randomized block design.

The two grading treatments were (1) smooth grading with tracking-in and (2) loose grading with a single pass. It took approximately 3 to 3.5 extra machine hours per acre to achieve the heavier grading. Three one-acre groundcover treatments were sown on each grading treatment plot: (1) a conventional mix of species intended to create the highest rate of groundcover (Fig. 7); (2) a tree-compatible mix (Powell River Project mix) intended to create a moderate rate of groundcover (Fig. 8); and (3) a native invasion mix intended to create the lowest rate of groundcover (Fig. 9, Table 2). Block 1 was hydroseeded in the fall of 2007, Block 2 in the winter of 2007-2008, and Block 3 in the early spring of 2008. All sites were planted with the same mix of native trees (Table 1) by a commercial tree-planting contractor in mid-January of 2008.

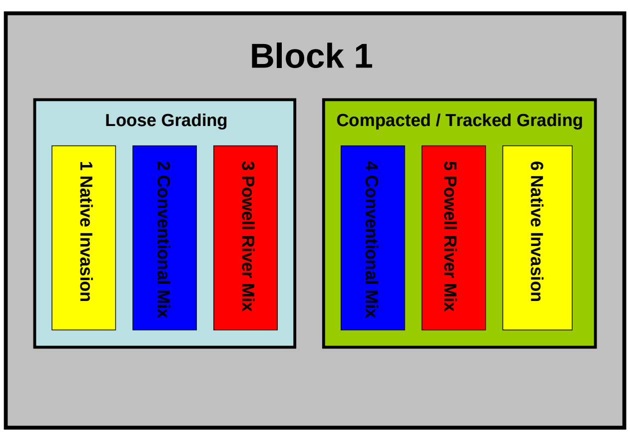

Figure 1. Conceptual map of the layout of experimental blocks using Block 1, Red River Coal site, as an example.

Figure 2. Location of Blocks 1 and 2 near Norton, Virginia.

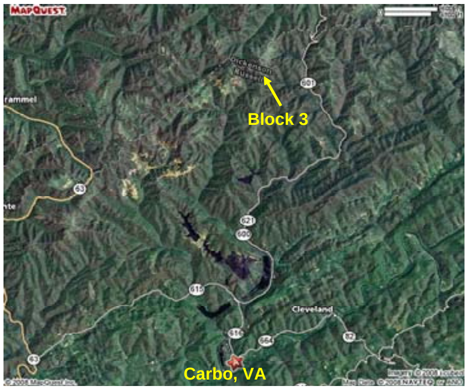

Figure 3. Location of Block 3 near Carbo, Virginia.

Figure 4. Block 1, winter 2007-2008.

Figure 5. Block 2, winter 2007-2008.

Figure 6. Block 3, winter 2007-2008.

Figure 7. Conventional mix, August 2008.

Figure 8. Powell River Project mix, August 2008.

Figure 9. Native invasion mix, August 2008.

Table 1. Tree planting prescription for all experimental plots.

Species	Trees Planted/Acre
yellow poplar (*Liriodendron tulipifera*)	50
white oak (*Quercus alba*)	83
chestnut oak (*Quercus prinus*)	83
black oak (*Qurecus velutina*)	83
red oak (*Quercus rubra*)	83
sugar maple (*Acer saccharum*)	83
black cherry (*Prunus serotina*)	83
white ash (*Fraxinus allegheniensis*)	83
shagbark hickory (*Carya ovata*)	25
white pine (*Pinus strobus*)	37
redbud (*Cercis canadensis*)	22
gray dogwood (*Cornus racemosa*)	22
red mulberry (*Morus rubra*)	10
Total	**747**

Table 2. Seed, fertilizer and mulch mixtures for groundcover treatments.

Mixture	Rate (lbs/ac)
Native Plant Invasion Mix	
Seed Mix:	
Annual ryegrass (*Lolium multiflorum*)	20
Diammonium Phosphate 18-46-0	300
Wood Cellulose Fiber	1500
Powell River Project Mix	
Seed Mix:	
Annual ryegrass (*Lolium multiflorum*)	20
Perennial ryegrass (*Lolium perenne*)	10
Timothy (*Phleum pretense*)	5
Birdsfoot trefoil (*Lotus corniculatus*)	5
Ladino clover (*Trifolium repens*)	3
Weeping Lovegrass (*Eragrostis curvula*)	2
Diammonium phosphate 18-46-0	300
Wood Cellulose Fiber	1500
Conventional Mix	
Seed Mix:	
Rye grain (*Secale cereale*)	30
Orchardgrass (*Dactylis glomerata*)	20
Perennial ryegrass (*Lolium perenne*)	10
Korean lespedeza (*Lespedeza cuneata*)	5
Birdsfoot trefoil (*Lotus corniculatus)*	5
Ladino clover (*Trifolium repens*)	5
Redtop (*Agrostis gigantea)*	3
Weeping lovegrass (*Eragrostis curvula*)	2
16-27-14	400
Wood Cellulose Fiber	1500

Erosion and Sedimentation

Erosion pins made of half-inch steel rebar were used to estimate loss and accumulation of surface soil. Twelve erosion pins were installed in each of the 18 treatment plots of the experiment (Fig. 10).

Once installed, the pins were measured in height to the nearest millimeter on the uphill side. Thereafter, the pins were measured before the growing season in early April and after the growing season in late October.

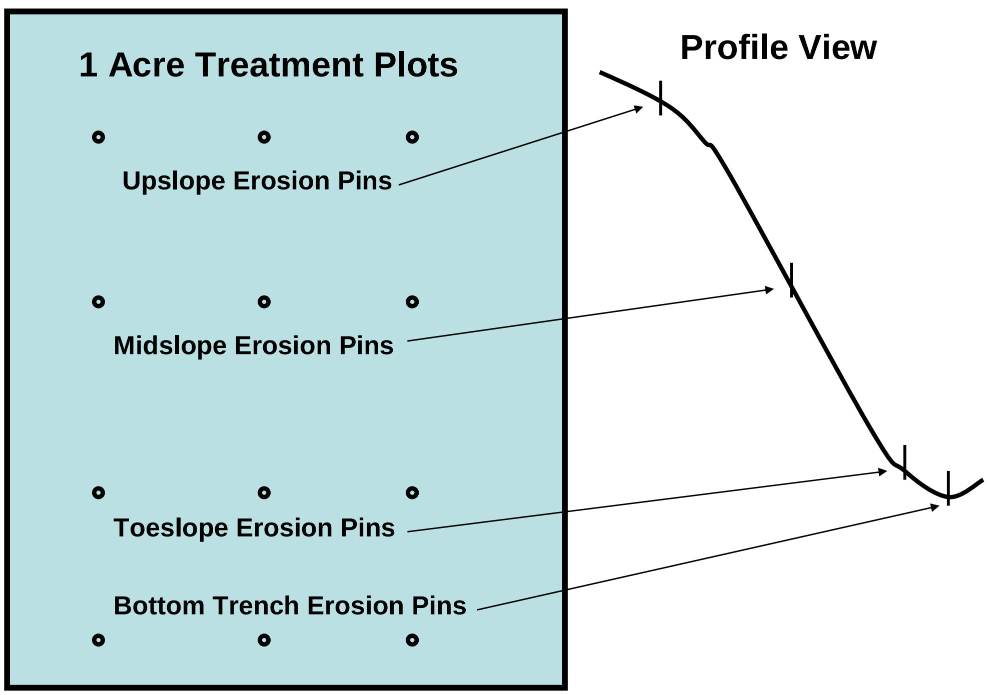

Figure 10. Conceptual map of erosion pin layout on all 18 treatment plots. Soil samples were taken 1 m to the right of each erosion pin, facing uphill.

Soil Sampling and Testing

Soil samples were gathered for each of the 18 plots. Samples were composed of nine subsamples taken within each plot 1 m from the erosion pins. The surface 2 inches of soil were removed in order to discard hydroseeding materials from the sample, and soil was collected from a depth of 2-6 inches for each subsample. The subsamples were combined and mixed for a single composite sample per plot. Soil samples were air-dried, then sieved through a #10 screen to separate the coarse and fine fractions. Samples were analyzed for pH, extractable cations, cation exchange capacity, soluble salts, and organic carbon content (Table 3). No significant differences in these chemical properties were found among treatment plots within blocks.

Table 3. Soil physical and chemical properties at onset of experiment, spring 2008.

Block	Grading	Cover Type	% Fines	pH	P (ppm)	K	Ca	Mn	Fe	CEC (meq/100g)	Acidity (%)	BS	OM	SS (ppm)
1	Loose	Native Invasion Mix	47	5.96	36	62	823	46.2	62.6	6.0	2.0	98.0	1.3	269
1	Loose	Conventional Mix	55	5.52	32	59	928	33.7	49.8	7.5	7.9	92.1	1.2	602
1	Loose	Powell River Project Mix	47	5.51	46	62	1284	42.5	79.7	9.6	6.2	93.8	1.2	909
1	Compact	Conventional Mix	50	4.59	27	50	774	44.2	73.7	7.6	24.3	75.7	1.2	563
1	Compact	Powell River Project Mix	40	5.80	70	62	1447	60.7	86.6	10.1	2.4	97.6	1.2	973
1	Compact	Native Invasion Mix	48	6.93	49	75	977	63.9	73.6	7.2	0.1	99.9	1.5	115
2	Loose	Native Invasion Mix	27	7.93	47	74	2617	135.3	197	17.4	N/A	100.0	1.6	218
2	Loose	Conventional Mix	29	8.10	22	66	3009	160.7	122.5	19.6	N/A	100.0	1.4	218
2	Loose	Powell River Project Mix	45	7.46	78	63	1309	86.4	77.3	9.6	N/A	100.0	2.0	230
2	Compact	Conventional Mix	42	7.21	75	60	1466	80.7	71.2	10.3	N/A	100.0	1.8	627
2	Compact	Powell River Project Mix	39	7.20	77	64	1122	69.4	68.7	8.4	N/A	100.0	2.3	218
2	Compact	Native Invasion Mix	36	6.76	70	66	1120	58.7	65.8	8.1	0.1	99.9	1.8	384
3	Loose	Powell River Project Mix	45	7.19	28	44	910	35.8	42.5	6.3	N/A	100.0	0.9	51
3	Loose	Native Invasion Mix	30	6.76	41	48	740	43.6	54.9	5.7	0.5	99.5	0.9	51
3	Loose	Conventional Mix	41	7.20	48	51	1036	54.6	66.8	7.7	N/A	100.0	0.8	77
3	Compact	Conventional Mix	32	6.23	46	47	846	37.5	45	6.9	0.9	99.1	0.9	64
3	Compact	Powell River Project Mix	37	7.02	52	50	1088	44.4	49.7	8.4	N/A	100.0	0.9	51
3	Compact	Native Invasion Mix	42	6.95	43	49	949	43.4	53.4	7.3	N/A	100.0	0.9	64

American Chestnut Planting

Six genotypes of American chestnuts, provided by the American Chestnut Foundation, were planted on all of the loose-graded plots from March 14-17, 2008. Chestnut seeds were planted and protected using procedures developed by the American Chestnut Foundation (Fig. 11). These procedures involved digging a 4-inch wide x 8-inch deep hole, filling it with a mix of potting soil, native forest topsoil for biotic inoculation, and on-site mine soil. Seeds were then placed on top of this medium and covered with an additional 1-inch layer of soil medium. Tree tubes (15 inches tall) were then placed 1 inch deep into the ground around the seed and planting medium and staked with a piece of 3/8-inch rebar. Rocks were piled around the base of each tube to the height of a few inches. Planting was performed in late March and germination was first checked in early May. Thereafter, survival, tree height to the highest live bud, canopy diameter, and stem diameter at the height of the top of the tree tube were measured in late October to early November at the conclusion of the growing season.

Figure 11. Photo of chestnut planting method taken in March 2008.

Vegetation Sampling

Five 1/20-ac circular woody plant measurement plots were established on each treatment plot (Fig. 12).

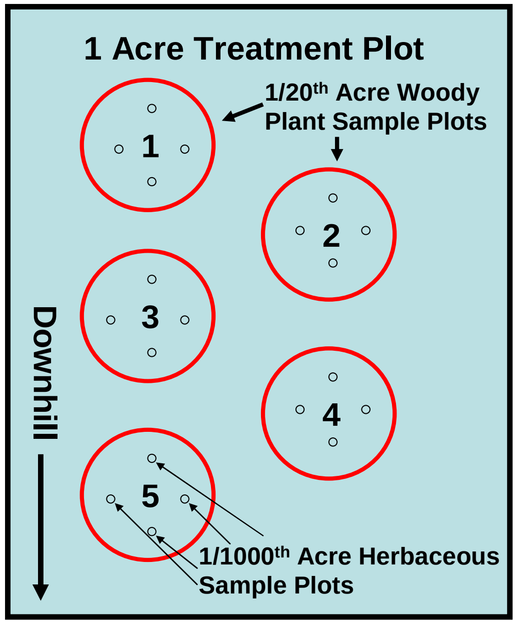

Figure 12. Conceptual diagram of vegetation sampling plots for all 18 treatment plots.

Groundline diameter and tree height to the highest live bud were measured for all trees within measurement plots. Groundline diameter measurements were not taken for chestnut trees as they were still contained in tree tubes. Additionally, four 1/1000-ac herbaceous plant measurement plots were nested inside of each woody plant measuring plot. Within each measuring plot, total groundcover was estimated using an ocular method by comparing observed ground coverage with diagrams of various coverages typically used for determining percent mottling in soils. Percent groundcover by species was estimated in the same way. Plant samples of all species encountered were collected for identification. Pictures of each herbaceous plot were taken.

Statistical Analysis

Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences in performance characteristics among treatments were determined using a randomized block ANOVA. Tukey-Kramer HSD was used for mean separations ($P < 0.05$ and $P < 0.10$). Multi-factor analysis was also performed to analyze treatment interactions and block effects.

Results

Compaction had no significant impact on survival of mixed hardwood trees or on the percent groundcover of herbaceous vegetation (Table 4). The conventional groundcover mix and the Powell River Project mix both produced significantly more groundcover than the native invasion mix. Groundcover type had no effect on tree survival, although the native invasion mix does appear to have nominally better survival than the other two mixes (Fig. 13).

The exposed height of erosion pins actually decreased over the time frame between erosion pin measurements, as indicated by positive soil surface change (Table 5), an unexpected result that was attributed to soil expansion caused by compression rebound, freeze-thaw processes, mineral slaking, moisture swell, and rooting expansion. Hence, these measurements are expressed as “surface change,” a relative measurement computed from the exposed heights of the erosion pins. Visual observations indicated that soil was being lost even at sites where measured surface change was positive. Surfaces in upslope positions eroded more (i.e., less positive surface change) than those in mid- and toeslope positions, and the tree-noncompetitive groundcover mixes (PRP and native invasion) eroded less than the conventional mix. Loose grading caused significantly less erosion than smooth and tracked-in grading (Fig. 14). There were no significant effects of groundcover type or landscape position on erosion.

Table 4. Treatment and block effects on groundcover rates and surviving trees per acre (TPA) with significant differences (Tukey HSD) by alpha (α) level.

	Groundcover	α = 0.05	α = 0.10	Survival (TPA)	α = 0.05	α = 0.10
Grading						
Compact	0.59	a	a	320	a	a
Loose	0.55	a	a	269	a	a
Block						
1 – RRC (Fall Seed)	0.81	a	a	296	a	a
3 – CR (Spring Seed)	0.62	a	b	272	a	a
2 – PRP (Winter Seed)	0.28	b	c	316	a	a
Groundcover						
Conventional	0.66	a	a	268	a	a
Powell River Project	0.61	a	a	252	a	a
Native Invasion	0.44	b	b	364	a	a

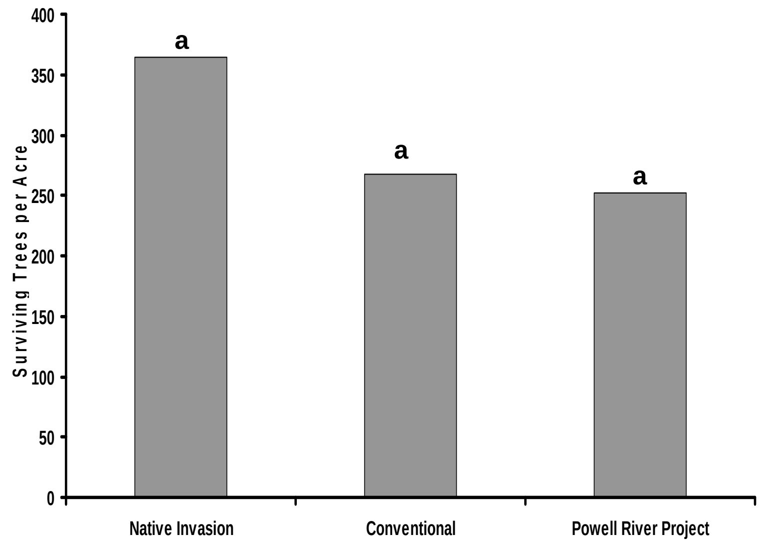

Figure 13. Trees per acre by groundcover treatment surviving the first growing season with significant differences at the α = 0.10 level indicated by different letters.

Table 5. Treatment and block effects on soil depth change over 230 days spanning the 2008 growing season with significant differences by alpha level.

	Soil Depth Change (mm)	α = 0.05	α = 0.10
Grading			
Loose	17	a	a
Compact	3	b	b
Block			
1 - RRC	9	a	a
2 - PRP	15	a	a
3 - CR	6	a	a
Groundcover			
Conventional	8	a	a
Powell River Project	11	a	a
Native Invasion	12	a	a
Landscape Position			
Upslope	7	a	a
Midslope	11	a	a
Toeslope	13	a	a

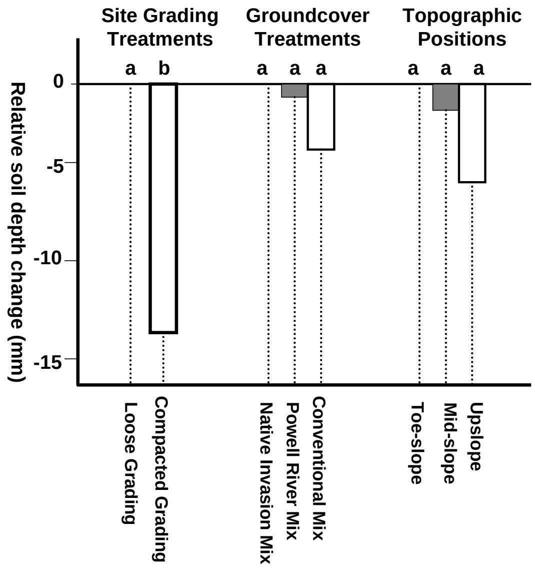

Figure 14. Relative change in soil surface among treatments. The treatment experiencing the least soil erosion was set as the baseline. Significance differences (α= 0.10 level) are shown by by different letters within treatment categories (grading, groundcover and topographic position).

Groundcover type had no significant effect on chestnut survival or growth (Table 6). There were significant differences in the performance of the genotypes. The Chinese chestnuts and hybrids with the highest proportion of Chinese genes grew fastest. Chinese chestnut had higher survival than one genotype of hybrid chestnut.

Table 6. Treatment, block and genotype effects on survival and growth of chestnut trees with significant differences by alpha level.

	Survival	α = 0.05	α = 0.10	Ht (mm)	α = 0.05	α = 0.10
Groundcover						
Native Invasion	0.75	a	a	247	a	a
Powell River Project	0.74	a	a	259	a	a
Conventional	0.63	a	a	233	a	a
Block						
2 - Powell River	0.80	a	a	236	a	a
1 - Red River Coal	0.70	ab	ab	253	a	a
3 - Carrie Ridge	0.63	b	b	250	a	a
Genotype						
2	0.88	a	a	331	a	a
3	0.80	ab	ab	303	a	ab
5	0.73	ab	ab	220	b	c
1A	0.69	ab	ab	202	b	c
1B	0.64	ab	ab	197	b	c
4	0.57	b	b	220	b	c
X	0.57	ab	ab	262	ab	bc

* Genotype Key: 1A = All-American; 1B = All-American; 2 = All-Chinese; 3 = ¾ American B1F3; 4 = 7/8 American B2F3; 5 = 15/16 American B3F2; X = genotype label lost.

Groundcover treatment and grading treatment had no effect on number of volunteer herbaceous species; however, there was a significant block effect (Table 7).

No significant interaction effects between groundcover type and grading type were found for tree survival, tree growth and erosion rates.

Table 7. Treatment and block effects on count of established volunteer species.

	Avg. Count of Volunteer Spp.	α = 0.05	α = 0.10
Groundcover			
Native Invasion	3.8	a	a
Powell River Project	3.0	a	a
Conventional	1.0	a	a
Block			
2 - PRP (Winter Hydroseed)	5.7	a	a
3 - CR (Spring Hydroseed)	1.8	ab	b
1 - RRC (Fall Hydroseed)	0.3	b	b
Grading			
Loose	2.8	a	a
Compact	2.4	a	a

Discussion

Different compaction levels did not result in significantly different groundcover rates or rates of tree survival after this first growing season (Table 4). It remains to be seen how the vegetation will respond when it becomes more fully established.

There were significant differences in the groundcover rates achieved by the different groundcover treatments (Table 4). Nominally, the conventional mix of grasses and legumes grew more coverage than the Powell River Project mix that is designed to be less competitive with trees. Statistically, the native invasion treatment grew less groundcover than the other two treatments. We hypothesized that this would occur and that having less groundcover will allow these treatment plots to accumulate more volunteer vegetation, thus facilitating succession.

Groundcover type did have significant effects on surviving tree counts, and thus on apparent survival, a result that supported the research hypothesis. The native invasion treatment allowed higher tree survival than the Powell River Project or conventional treatments (Table 4). Therefore, annual rye alone may be a viable alternative groundcover in terms of promoting tree survival while achieving other reclamation goals (Groninger et al. 2007).

We hypothesized that the three experimental groundcover treatments would perform equally well at controlling erosion, and this hypothesis is supported (Fig. 16, Table 5). One implication of these data is that if one of these groundcover treatments exhibits superior performance characteristics in other categories besides erosion control, such as improving tree survival or increasing the rate of volunteer plant succession, then it might be favored for those other purposes. All treatments performed equally well at accomplishing the primary reclamation goal of erosion control. Continued monitoring of these plots is important, however, because the native invasion mix is specifically designed to fade out after the first year and yield to whatever naturally comes on to the site. Depending on what arrives and how much ground it covers, the erosion effects could change. Groundcover rates are thought to be connected to erosion rates, and that is supported by the fact that there were no significant differences in soil depth changes (erosion/deposition) or groundcover rates across the three groundcover treatments.

We hypothesized that higher levels of compaction would lead to higher levels of surface erosion, possibly due to an inability of water to infiltrate as quickly through compacted materials lacking macroporosity. This hypothesis is supported (Table 5). As no significant effect of compaction on groundcover was expected or found, the differing rates in soil erosion may have occurred due to the direct physical effects of compaction on soil rather than the indirect effects of compaction through promoting or inhibiting vegetation.

We expected that more net soil surface would be lost from upslope positions than from midslope and toeslope positions and that more net soil depth would be lost by midslope positions than by toeslope positions due to the deposition of eroded material into lower positions and the tendency of lower concave surfaces to accumulate more material than convex surfaces above. The data in Table 5 show no significant differences in rates of soil change among the landscape positions, although the hypothesis is nominally supported. Revegetation strategies might be improved by adapting them to topographic features and it is the goal of this aspect of the study to gather some relevant information on that issue while confirming whether the erosion pins are functioning as expected. Because of the stratified layout of the vegetative sampling plots along topographic gradients, it will be possible to also look at the effects of topographic position on the survival and growth of various woody and herbaceous species in this study.

We expected that the planted chestnut trees would respond to the three groundcover treatments the same as the other hardwoods. There were no significant differences in survival or height growth of chestnuts planted on the three different groundcover treatments (Table 6). The chestnuts were planted in tree tubes, giving them a degree of separation from herbaceous competition, so it stands to reason that they would express less responsiveness to groundcover type at this early growth stage than the other unsheltered mixed hardwoods.

The all-Chinese chestnut genotype is demonstrating significantly higher survival rates than the 7/8 American-1/8 Chinese (Table 6), but all other hybrids were the same. We expected the genotypes with the highest proportion of Chinese genes to have higher survival rates than the all-American and more strongly American genotypes, and this was confirmed nominally, though only partially statistically. The all-Chinese genotype is also demonstrating significantly more height growth than most of the mixed genotypes and all of the all-American genotypes (Table 6). No significant differences in survival or growth have been observed yet among the American or hybrid genotypes, suggesting that either there are not strong differences in genetic potential between these genotypes or that potential differences have not yet expressed themselves.

The inability to control the size of tree seedlings planted confounds the growth data of the mixed hardwoods other than chestnut for the first year. Measurements of height and groundline diameter for the mixed hardwoods were taken at the end of the 2008 growing season; however, these data will not be useful until the data from 2009 are available with which to make a comparison of actual growth. Survival data is also premature for the mixed hardwoods, as the exact number planted in the beginning of the 2008 growing season is unknown.

The native invasion groundcover treatment did have the highest nominal number of volunteer herbaceous species per treatment plot at the end of the first growing season (Table 8). We hypothesized that the lower rate of groundcover as well as the annual lifecycle of annual rye would allow for faster rates of volunteer plant recruitment and succession. It may take multiple growing seasons to differentiate, if at all. If it does, that will indicate that planting annual rye only is a faster path of natural succession. A further research question is whether the lack of legumes will reduce the productivity of the system in the long term by reducing the accumulation of nitrogen. If it does, then choices would have to be made between the desire for faster succession and accumulation of volunteer plant species versus long-term forest productivity effects of the legume-accumulated nitrogen.

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Use of Reclaimed Mined Land for Woody Biomass Production: Installation and Year One Results

Daniel M. Evans, Carl E. Zipper, James A. Burger, and Chris Fields-Johnson

Introduction

The extensive hardwood forests of the Appalachian Mountains could help meet the current and future demand for biomass materials for energy production. However, the long-term outlook for this commodity market is uncertain. If demand for energy increases or future government policies limit carbon emissions from energy production, demand for carbon-neutral fuels such as biomass products may increase. Additionally, the construction of "hybrid" power plants in the Appalachian region that are contracted to burn a percentage of non-coal materials will increase demand for biomass products. For example, Dominion Resources' Virginia City Hybrid Energy Center, currently under construction in Wise County, will use coal and up to 20 percent biomass for its fuel (Dominion Resources 2009).

Under-utilized mined lands in the coalfields of Virginia and surrounding coal-producing states could provide biomass fuels in addition to those that can be harvested sustainably from non-mined native forest land to fuel power plants and to provide woody biomass for emerging technologies such as cellulosic biofuels. There are many advantages and benefits of using mined lands to produce biomass materials. If mined land can provide increased biomass production, it will reduce the impact on native forests, which can be used for traditional forest products and ecosystem services. Local economies also benefit through the production of a renewable forest product on lands deemed unproductive by past generations.

Research has demonstrated that properly reclaimed mined lands can be highly productive (Burger and Fannon 2009, Burger 2004). Fast-growing tree crops, such as hybrid poplar or black locust, are most productive when they are able to extend their root systems to exploit large soil volumes. Mine soils offer soil-like materials comprised of freshly fractured rocks at thicknesses far deeper than many of the region's natural soils. These freshly-fractured geologic materials often have chemical characteristics, including pH levels and nutrient cation availabilities, that are favorable to plant growth (Burger et al. 2007).

More than 100,000 acres in the southwestern Virginia coalfields and about 1.5 million acres throughout Appalachia have been mined for coal and reclaimed under the Surface Mining Control and Reclamation Act of 1977, and many of these areas remain accessible because mining access roads were left in place. Research on unmined lands suggests that productivity (tons of biomass produced per acre per year) of fast-growing woody crops growing on favorable sites can be on the order of 3 to 5 times that of long-rotation natural forests on mountainous sites (Amichev 2007). For example, in an analysis of data collected from eight unmined native hardwood forest areas adjacent to coal mining areas, Amichev (2007) found that total tree carbon accumulation averaged 0.85 Mg C ac^{-1} yr^{-1} (2.1 Mg C ha^{-1} yr^{-1}) over 60-year rotations. In contrast, he estimated that hybrid poplar growing on favorable sites with short rotations in a similar climate have the potential to accumulate total tree C at a rate of 4.44 Mg C ac^{-1} yr^{-1} (11 Mg C ha^{-1} yr^{-1}).

Past mining practices have left many sites with highly degraded site productivity due to soil compaction and lack of tree-compatible vegetation. We hypothesize that mined sites with favorable soil chemical characteristics can be managed for intensive tree biomass production regardless of past soil and vegetation management. This study is designed to test the capability of previously mined lands to be used for tree biomass production. It tests biomass production for differing tree species and planting densities. This report summarizes our methods and initial tree survival one year after planting. This study is part of a greater research effort that is intended to achieve four goals:

1. Measure and compare biomass production of woody and herbaceous biofuel crops on mined lands.
2. Measure and compare optimum harvest cycles of woody crops on mined land.
3. Determine the potential of herbaceous and woody biofuel/bioenergy crops growing under optimal soil conditions to sequester atmospheric carbon in above-ground and below-ground forms.
4. Develop and describe a method for preparing mined sites that have been reclaimed in previous years and are currently unused for biofuels production.

Methods and Future Management Plan

Three sites in Wise County, Virginia, were included as replicate blocks in this study (Fig. 1). Each site provided at least 5 ac (2 ha) of relatively flat ground (<15% slope) that could be reached by heavy equipment for site preparation and harvesting. In December 2007, each site was disked and ripped to till under existing vegetation and to alleviate possible compaction, leaving loose soil for tree planting and root growth (Photo 1). This was accomplished with a heavy forestland disc harrow used to break up the soil, followed by a second pass to deep-till and mound the tree planting row. The tillage tool had a 3-ft center shank that ripped a deep trench through the compacted mine soil, while large disks around the shank produced a mound of loose soil over the rip where the trees are planted. Smaller shanks to the right and left of the center shank broke up the surface to 1 ft on either side of the planting location.

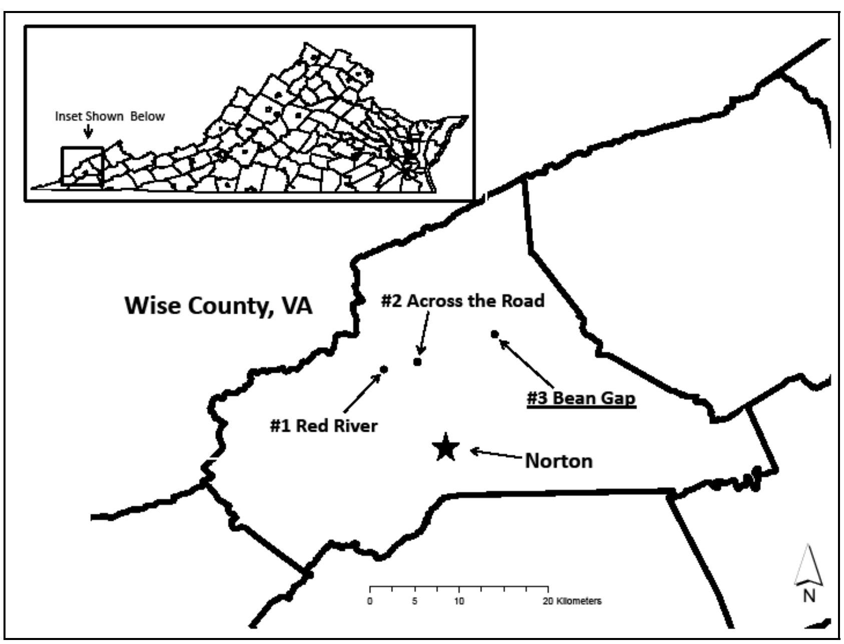

Figure 1. Biomass block locations in Wise County, Virginia.

Photo 1. An advanced ripping tool used to prepare the biomass research sites by Union Concrete Products of Maxwelton, West Virginia, under the direction of J. K. Rose.

Each of the three sites was broken down into four treatment areas of approximately 0.5 acres (Figs. 2-4). Trees were planted by Williams Forestry and Associates in January 2008. In the early winter of 2008, each treatment plot received hybrid poplar (*Populus sp.* x *Populus sp*.), sycamore (*Platanus occidentalis*), and black locust (*Robinia pseudoacacia*), planted at two densities. The low-density treatment was planted along the 11-ft furrows with an intended target of 11 x 11 ft spacing or 450 trees ac^{-1} (1100 trees ha^{-1}). The high-density treatment was planted at half the distance between trees, both on the furrows and in between the furrows, with an intended target of 5.5 x 5.5 ft spacing or 1400 trees ac^{-1} (3400 trees ha^{-1}).

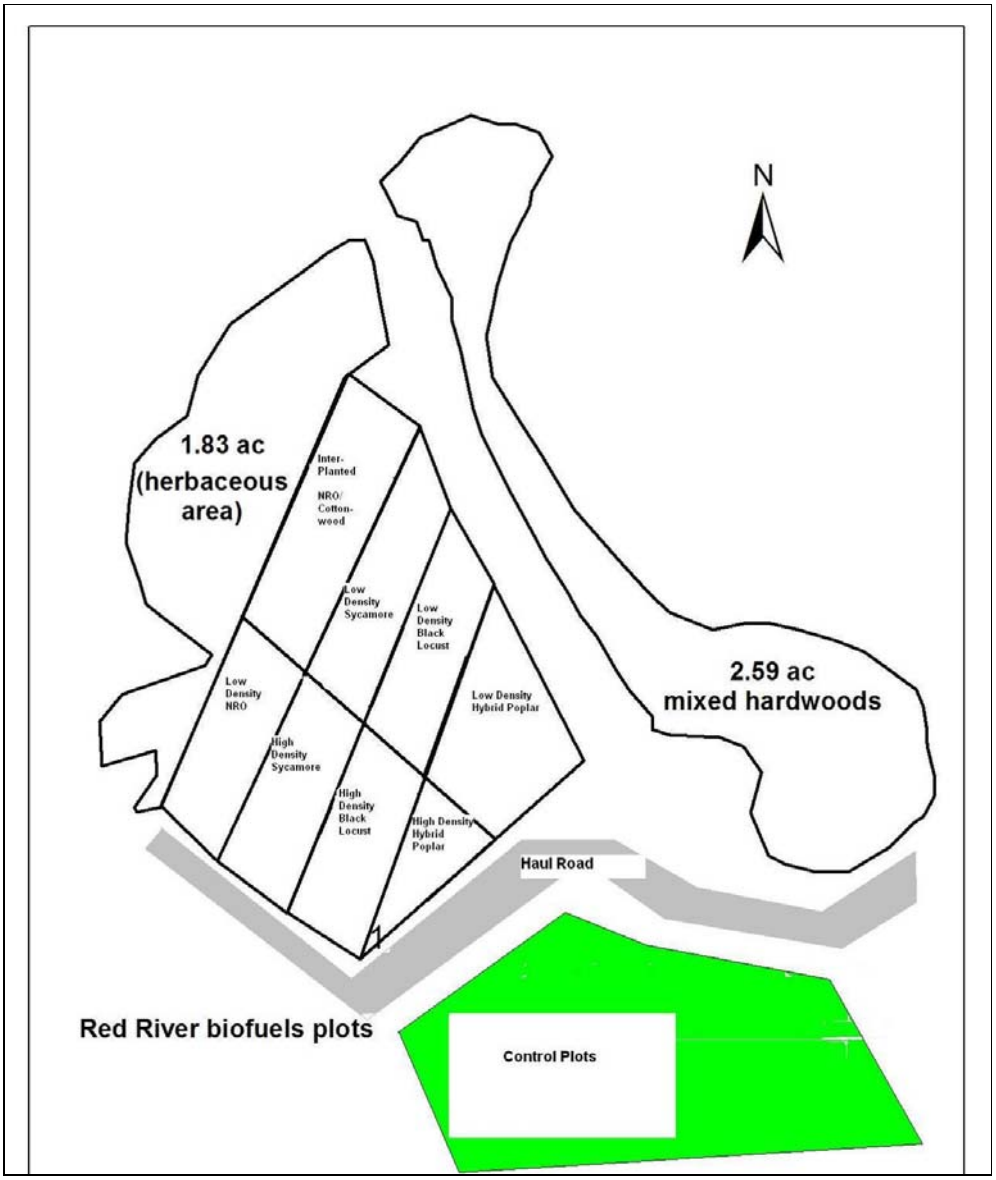

Figure 2 . Treatment plot layout at Block 1 (Red River). The "herbaceous areas" were established with the intention of establishing fast-growing herbaceous crops, such as switchgrass, to enable direct comparison of biomass production rates with the woody crops, but available funding did not enable herbaceous crop establishment.

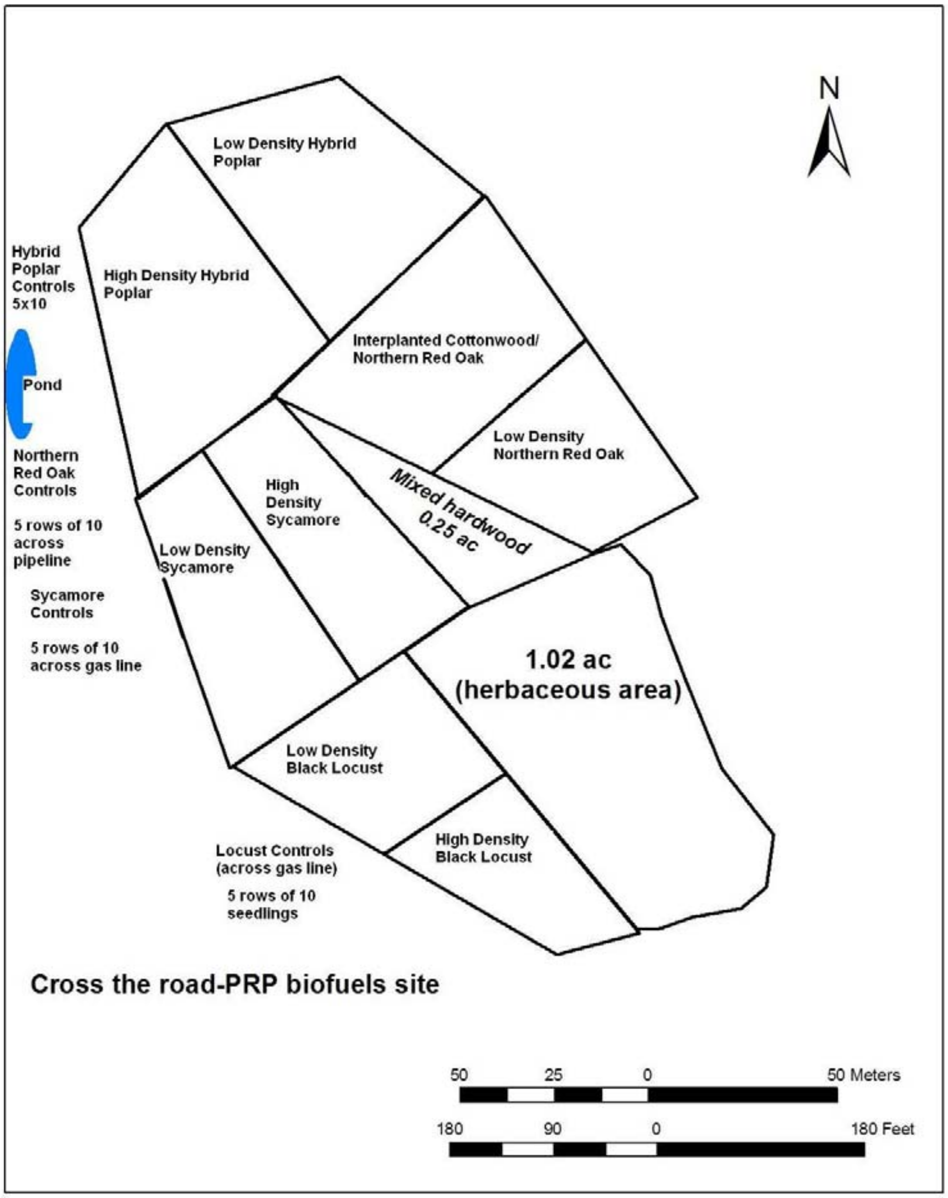

Figure 3. Treatment plot layout at Block 2 (Across the Road).

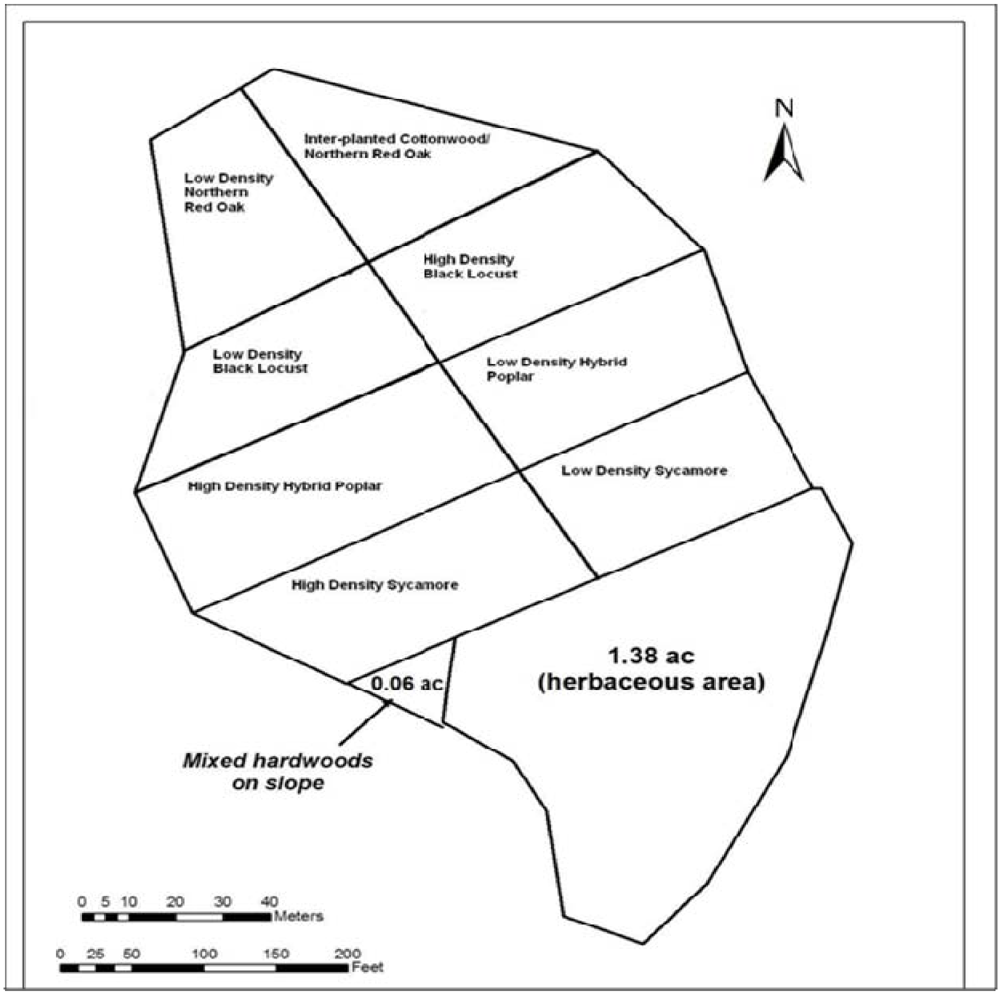

Figure 4. Treatment layout at Block 3 (Bean Gap).

Harvesting methods drove the rationale for these planting densities. The high-density planting is suitable for harvesting at a very young age (5-10 years) using a "mowing and chipping" type of harvesting equipment with an operating mechanism that resembles agricultural harvest equipment. The low-density planting would be suitable for harvesting with traditional whole-tree forestry equipment after a longer rotation. Within each treatment area and planting density, we installed permanent measurement plots of 7500 ft^2 (700 m^2). A few treatment areas were in non-homogeneous areas of the unit, so we reduced the size of these measurement areas to ensure relatively homogeneous ground in each treatment (Table 1).

Table 1. Biomass Year 1 stocking (measured March 2009).

	N	Mean Ht. (in)	Mean GLD (in)	Area (ft^2)	Trees ac^{-1}
Block 1 (Red River)					
High-density black locust	210	35.6	0.5	7500	1220
Low-density black locust	69	41.5	0.6	7500	401
High-density hybrid poplar	184	23.8	0.3	7500	1069
Low-density hybrid poplar	83	29.2	0.4	7500	482
Red oak	102	19.3	0.2	7500	592
Red oak/cottonwood	91/77	17.9/16.0	0.2/0.2	7500	976
High-density sycamore	154	18.5	0.3	7500	894
Low-density sycamore	40	17.9	0.4	7500	232
Mixed hardwood	46	20.0	0.3	7500	267
Block 2 (Across the Road)					
High-density black locust	164	31.7	0.5	6000	1191
Low-density black locust	55	30.5	0.5	5000	479
High-density hybrid poplar	130	21.8	0.4	7500	755
Low-density hybrid poplar	47	20.1	0.4	7500	273
Red oak	87	14.3	0.2	6000	632
Red oak/cottonwood	107/120	16.6/15.6	0.2/0.2	7500	1318
High-density sycamore	244	17.1	0.3	7500	1417
Low-density sycamore	62	15.4	0.3	7500	360
Mixed hardwood	20	11.5	0.2	2812	310
Block 3 (Bean Gap)					
High-density black locust	209	30.7	0.4	7500	1214
Low-density black locust	84	43.6	0.6	7500	488
High-density hybrid poplar	216	19.7	0.2	7500	1255
Low-density hybrid poplar	87	16.2	0.2	7500	505
Red oak	101	17.5	0.2	5000	880
Red oak/cottonwood	115/110	18.0/16.0	0.2/0.2	7500	1307
High-density sycamore	136	19.2	0.3	6250	948
Low-density sycamore	80	18.9	0.3	7500	465
Mixed hardwood	29	26.1	0.3	1250	1011

A fourth treatment included an additional high-density treatment of northern red oak (*Quercus rubra*) (11 x 11 ft) interplanted with rows of eastern cottonwood (*Populus deltoides*) (5.5 ft within row). This treatment was included to test the use of the fast-growing eastern cottonwood's ability to train the slower-growing but higher-value red oak. Red oak is a high-value sawtimber species that is native to Appalachian forests. The value of red oak as sawtimber can be increased by training its stem form at an early age by interplanting with eastern cottonwood, which can be harvested for biomass products at a relatively short rotation age. A low-density red oak treatment (11 x 11 ft) without cottonwood was included to compare against the interplanted red oaks. A final treatment of mixed hardwoods was included where space allowed, comparing biomass production of the more common planting of mixed hardwoods at low planting density (8 x 8 ft or 680 trees ac^{-1}).

In the late spring of both 2008 and 2009, a release spray of 2% glyphosate was used to reduce competition from weeds in a 3-ft (1-m) diameter circle around each of the trees in the treatment area. This spray was hand-applied using backpack sprayers. Because of a droughty summer in 2008 and low viability of seedling stock, red oak and eastern cottonwood survival was poor. Therefore, we replanted the red oaks and eastern cottonwoods in the late winter of 2008 to bring the density back to desired levels. In March of 2009 we measured each of the treatment areas for survival, height and groundline diameter (GLD).

Estimated rotation ages are 12 years for the hybrid poplar, black locust, and sycamore biomass crop, with a 60-year rotation for the red oak sawlog crop. The hybrid poplar and black locust will be grown strictly for biomass products. Although it is among the fastest-growing native Appalachian hardwood species when planted on suitable soils, the growth rate of sycamore is not as fast as those of black locust and hybrid poplar. However, its value at rotation age will be much higher if its butt log is used for sawtimber while the rest of the tree is chipped for biomass products. At age 12, the interplanted eastern cottonwood will be row-thinned and the red oaks will be left free to grow for a sawtimber rotation. The interplanted treatment will evaluate the silvicultural response of the oaks (i.e., determine whether or not the faster-growing poplars "train" the oaks to achieve a straight and tall stem form which is highly valued in timber markets) to the interplanted eastern cottonwoods, as well as total biomass production. This treatment will also help determine the effect of early revenue from biomass on a sawtimber forest enterprise.

Initial Results

Our initial measurement of survival indicates that the planting was successful (Table 1). Stocking levels are close to our projected levels. However, there is a range of stocking levels at each site and for each treatment. High-density first-year stocking ranged from 755 to 1317 trees ac^{-1}, while low-density stocking ranged from 232 to 505 trees ac^{-1}. Due to this range of stocking levels, future biomass production estimates will be conducted on a per-tree and per-acre basis to allow land managers to estimate probable operational biomass production.

Black locust had the highest mean height and groundline diameter at all three sites. Hybrid poplar generally had the next highest mean height and groundline diameter, with sycamore being slightly smaller at Year 1. The red oak and eastern cottonwood have the smallest mean heights and groundline diameters at Year 1. We did not calculate biomass or carbon production using these Year 1 measurements. Measurements at Year 3 or Year 5 will be used for an initial estimate of comparative species performance.

Future Analysis

We plan to track growth over the rotation ages for each treatment with a focus on aboveground biomass production, above- and belowground carbon sequestration, and sawtimber production. Analysis will be conducted addressing optimum harvest scheduling timing, as well as per-acre expenditures and possible revenue streams for all of the management scenarios that this study represents.

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Hybrid Poplar for Bioenergy and Biomaterials Feedstock Production on Appalachian Reclaimed Mine Land

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Introduction

Use of Appalachian mined lands for biobased products could help increase energy security, enhance the rural economy, and enhance the environment without displacing land for food production. However, achieving a sustainable biomass-based industry is contingent on the breeding, testing and selection of dedicated perennial cellulosic energy crops specifically for this region.

Poplars (genus *Populus)* and their hybrids are widely considered to be the premier woody perennial candidate for bioenergy feedstock production (De La Torre Ugarte et al. 2003; Perlack et al. 2005). Poplar plantation silviculture is highly refined and commercial stands have been successfully managed through multiple rotations by the pulp and paper, timber, and the environmental-remediation industries in a number of regions throughout North America. Hybrid poplar offers several important advantages including: 1) poplars are the fastest growing temperate zone tree with growth rates approximating 20 bone dry metric tons per hectare per year (total biomass) achieved on six-to-eight year rotations in commercial plantations of the Pacific Northwest (Stanton et al. 2002); 2) biomass can be stored "on the stump". It can be harvested year-round and, therefore, does not require the same level of investment in drying and storage facilities necessitated by herbaceous energy crops to prevent microbial degradation (Wright 1994); and 3) The net effect of poplar cropping systems on greenhouse gas emissions compares very favorably to those of other cellulosic crops owing to their less frequent tillage and cutting cycles (Adler et al. 2007).

Although hybrid poplar has not been developed specifically for Appalachian reclaimed mine lands, there is strong evidence supporting that it can be a productive energy crop for these regions. For example, a four-year study on reclaimed mine lands in Virginia, Ohio and West Virginia compared hybrid poplar clone 52-225 (Populus trichocarpa x P. deltoides), mixed Appalachian hardwoods, and Eastern White Pine (Fields-Johnson et al. 2008). On all sites, the hybrid poplar had superior growth, with 72 times more biomass than the hardwoods and 39 times more than pine.

Experimental Approach

Our specific objectives are to: (1) Field test 98 clonally replicated genotypes of three major inter-specific taxa at the Powell River Project (PRP) site and two sites in the Southside region, and (2) To provide education and training to farmers and landowners, and inform potential investors and other interested parties, we will host a "Hybrid Poplar for Bioenergy" symposium at the Institute for Advanced Learning and Research in Danville, VA and workshops at the field sites.

Figure 1. Hybrid poplars on a reclaimed mine site in Wise County, Virginia, in their 6th growing season.

The intent of the trial is to provide the earliest scientific data on superior varieties for commercial biomass production in this region. First, we will identify the correct suitability ranking of the taxa based on their growth rate and adaptability to the climate, soil, and pathogen pressure of the planting sites. Secondly, we will assess the range of genotypic variation within taxa as a preliminary assessment of the potential genetic gain that will attend a long-term reciprocal recurrent hybridization program for Appalachian reclaimed mine land and Piedmont.

Trials were established in Spring 2009. Ten inch dormant stem cuttings were planted at a 10 feet X 2 feet spacing in a randomized block design with four replications per site. Clones (Table 1) were blocked by taxa with border rows for each block. Following second year varietal evaluation, above-ground biomass will be harvested and analyzed (2010), and coppicing ability of the varietals assessed (2011). Initial crop production (growth and yield) models will be developed. Results from these trials will be utilized to select varietals for yield verification studies that will confirm selections of superior first-generation commercial varietals.

Table 1. Summary of hybrid poplar clones being evaluated

Taxon	**Number of Experimental Clones**
Populus x generosa (P. deltoides x P. trichocarpa)	33
Populus x Canadensis (P. deltoides x P. nigra)	32
Populus deltoides x Populus maximowiczii	33
Total	98

Figure 2. Preparing the experimental site in December, 2007. The large disk (left) is used first to break up the sod, then an advanced ripping device (right) was used to prepare the land for planting. See Evans et al. (2009) for further details.

Progress at the Powell River Project Site

The planting site is located on top of a hollow fill that was constructed by coal mining operations in the early 1990s. The site had been reclaimed with herbaceous vegetation in accord with standard coal mine reclamation practices for that time. The site was released from all regulatory obligations prior to current research activities.

By December of 2007, vegetation had become a mix of herbaceous and invasive woody vegetation. A few native hardwood trees had been planted on parts of the site for research/demonstration purposes in earlier years but were not thriving, possibly due to deficiency of essential nutrients. The site was prepared using deep tillage in December of 2007 (Figure 2) using the same implements and procedure described by Evans et. al. (2009).

In March and April of 2009, the site was prepared for the research planting. Four blocks were prepared, each comprised of 5 rows (3 interior rows for the test planting, and 2 exterior rows for the border planting) at 9-to-10 foot spacing and approximately 90 feet in length.

Figure 3. The hybrid poplar test site at Powell River Project Research and Education Center in Wise County, Virginia, 15 August 2009, 3 ½ months after planting.

The surface created by deep tillage was irregular, with mounds and depressions evident in some areas. Surface soils were redistributed manually as needed to prepare regular planting rows over the deep rips but with fewer differences in microtopography than the tilled surface. The surface reconfiguration was intended to assure that none of the test plantings were in depressions where water would accumulate in these poorly-drained minesoils, as observations of prior plantings indicated that such microsite conditions depress hybrid poplar survival and growth.

The site was limed using pelletized limestone with a hand-operated broadcast spreader based on soil test recommendations to pH 6.8. (2 tons/acre rate for Block 1, 4 tons/acre rate for Block 2, 3 tons/acre Blocks 3 and 4). Triple super phosphate fertilizer (0-45-0) was applied using a hand-operated broadcast spreader, achieving an average rate of 81 lbs. P per acre over the planting area. Additional fertilization (18-9-8) was applied in an 24-inch band over the planting rows with a hand operated drop spreader with the intention of applying 25 lbs. N per acre, averaged over the planting-row bands and intervening spaces; actual application was about 30 lbs N / acre plus associated P and K. The N fertilization was confined to a band application with the intent of limiting herbaceous competition within the test planting.

A glyphosate herbicide was applied to visible vegetation within the planting rows approximately 20 hours prior to the hybrid poplar planting. The site was planted on May 1, 2009 [survivability was high during the establishment phase (Figure 3, Table 2). Manual weed control was applied periodically to the planting site over the summer.

Table 2. Early survival of trees at the PRP test site assessed on May 20, 2009

Rank	Test trees (percent)
Bud flushed, good vigor	93% (n=366)
Bud flushed, poor vigor	3% (n=13)
No bud flush	4% (n=17)

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Herbaceous Crops for a Biofuels/Bioproducts Industry on Reclaimed Mine Lands

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Summary

In 2007, a biofuel species comparison was begun to investigate yield capacity of several feedstock species with potential suitability for revegetating mined land. Feedstock treatments included panicgrass, switchgrass, a 1:1 seed mix of panic- and switchgrasses, and two species established from vegetative propagules: hardy sugarcane and miscanthus. Plants were established at the Powell River Project Research and Education Center on 30 May 2007. Miscanthus plants were re-established in 2008: The original miscanthus species was mis-identified and this species was thus removed and replanted. Conditions for establishment were difficult due to drought, but about 70% of plants set out the previous season had new growth as of May 2009. Dead plants will be re-placed in May 2009. Initial survival and growth suggest miscanthus may be well-suited to production on mine lands. Across three harvests, average yields from all biofuel species are low (about 0.5 tons per acre at first harvest) with about 33% yield loss with delayed harvest. Growing season conditions and fertility have been limited, but N has not been applied in order to help reduce weed competition during establishment. Fertilizer N is to be applied in May 2009.

I. Introduction:

Renewable, bio-based chemicals and energy sources are of increased interest for nation, environmental, and economic security reasons. Few arising agricultural enterprises have the potential for such broad-scale impact as biorenewables industries, whether in terms of economics or land-use change. Sites with limited agricultural production capacity are of particular interest, because using such lands will avoid competition between food and fuel production. Evaluation and discovery of species with potential adaptation to mined land conditions may be an important part of meeting the nation's future needs.

Yield per land area will be an important determinant for economic viability of a biomass-to-biorenewables industry. Because raw biomass will be a low-value commodity (in dollars per ton), yields must be sufficient to warrant producer adoption and market entry. Given the extensive nature of sometimes difficult terrain, these sites will also need to be productive with minimal inputs.

II. Objectives:

1. Evaluate and compare stand establishment of potential biofuel/bioproduct crops (switchgrass, coastal panicgrass, and a mix of these two native grasses, along with two non-natives, miscanthus, and hardy sugarcane) on reclaimed mine lands in Southwest Virginia.
2. Evaluate these crops for growth traits such as plant height, crown width, tiller number, lodging, and leaf:stem ratio that relate to yield and feedstock quality.
3. Quantify yields in the establishment year and succeeding years.
4. Examine feedstock quality (cellulose, hemicellulose, lignin, nitrogen, and ash) of these potential biomass crops.
5. Determine the carbon sequestration potential of these biomass crops.

III. Methods and Procedures:

<u>Plant species</u>: Switchgrass, coastal panicgrass, and a 1:1 mixture of these species were seeded into plots with a plot seeder on 30 May 2007. At the same time, 100 plants/plot were established for both miscanthus and hardy sugarcane. Subsequent research determined that the miscanthus species planted in 2007 was not the species intended, and these plants were killed out and replaced in summer of 2008.

<u>Measurements</u>: Stand counts and plant growth measurements such as height, crown width, and tiller number were in October 2007 to determine initial production. Biomass samples were collected in January 2008, and plots also were evaluated for frost heaving. In March 2008, plots were evaluated for winter kill.

Biomass harvests were again conducted in Fall-Winter '08–'09 (three harvests) to determine change in yield of senesced plants over time. Survival of miscanthus plants established in 2008 also was measured in April 2009.

IV. Brief progress report:

Hardy sugarcane, the plant with best establishment in 2007, has suffered from large winter losses (greater than 50% in two of three reps). This species has been productive in some sites, but appears susceptible to soils with greater potential for freezing. Individual plants in better soil conditions have been highly productive, but use of this species would require high level of site selection. We continue to monitor these plants, but limited plant material – coupled with the large death losses – is leading us to abandon this species for use in mineland energy cropping.

Miscanthus survival has been 70% or more across all reps. Survival rates for plants (as opposed to root pieces) are often in the 80% range in Illinois (Tom Voigt, personal communication), so this level of survival should be a positive indicator. Observation suggests miscanthus is quite drought tolerant once established, but it is sensitive to drought during the establishment phase. Drought was an issue for this planting, so survival rates may be greater with higher summer precipitation.

Panic and switchgrasses produced greater amounts of biomass on a land area basis due to their distribution across the plot. Frost heaving has been a persistent issue on sites where soils hold water in the winter. We have replanted one rep with these soil conditions in April 2009.

Yields to date have been limited. About 0.5 t of standing biomass was harvested in November 2008, and yield declines were about 33% by March 2009 harvest. Although delayed harvests can improve feedstock quality (and often with limited yield losses), any gains in feedstock quality would be more than offset by such large yield losses.

We anticipate fertility is part of the limitation for plant productivity in these systems. Although much of the biomass research literature suggests little yield response to nitrogen fertilization for miscanthus and native grasses such as switchgrass, we anticipate greater yields with nitrogen applications given the lack of nitrogen in these soils.

Students are lined up to work on this and other biofuels projects through the coming year. We are meeting our objectives and excited to learn more about the potential of these species to produce biofuels on reclaimed lands.

Evaluating Wildlife Response to Vegetation Restoration on Reclaimed Mine Lands in Southwestern Virginia

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Environmental and land use studies are frequently conducted on reclaimed coal mines, but limited work has been done to determine the response of wildlife populations to these reclamation efforts. Land use typically changes following the mining process, and post-mining habitat and land-use may be strikingly different from their former composition. Changes in vegetative cover, vegetation type and composition, soil properties, and topography can provide different resources for wildlife than those previously available. There are opportunities to "improve" habitat, or at least provide substrates or topography that may be lacking in adjacent areas, if planned properly ahead of time (Scott and Zimmerman 1984).

Wildlife are often displaced from their native environments after mining, and may not return without the appropriate conditions necessary for their survival. Disturbances to wildlife during a mining operation include more than just excavation at the mine site. Impacts can be widespread and affect areas adjacent to and removed from the mine site. Other disturbances affecting wildlife and their habitat include the construction and use of temporary road systems and heavy machinery, noise, erosion, changes in topography and landforms, loss of native vegetation and cover, and sometimes environmental health concerns. Habitat complexity is often reduced following mining or other disturbances, causing a shift in the composition of wildlife communities such as birds (Wray et al. 1982). For example, a mature forest will support different species and abundances of birds than an open shrubland or managed pasture.

This project focused on studying avian and amphibian communities on reclaimed mine sites. Birds are generally one of the earliest species to visit a site following reclamation due to their mobility and active search for suitable habitat (Brändle et al. 2003). Although many studies have been conducted with birds on reclaimed sites, most have focused on the response of a single avian species (Balcerzak and Wood 2003, Bajema et al. 2001) or assemblage, such as grassland birds (Ingold 2002, Scott et al. 2002, Wray et al. 1982, Whitmore and Hall 1978). Amphibians are an ecologically sensitive group, frequently serving as important early indicators of poor environmental quality (Hyde and Simons 2001). Because amphibians are preyed upon by a variety of other species, they are believed to play an essential role in the cycling of nutrients into the food chain. Often these organisms are considered to be indicators of forest biodiversity (Welsh and Droege 2001), which illustrates the importance of understanding and considering anthropogenic impacts upon this species group. In the past 20 years, there have been substantial amphibian declines due to habitat disturbance and other anthropogenic influences (Alford and Richards 1999, Beebee and Griffiths 2005). Because of strong site fidelity and limited dispersal capacity, even small disturbances that result in fragmentation could isolate amphibians from important breeding or foraging habitat necessary for survival (Krishnamurthy 2003). Even though amphibian species that inhabit the coal-producing regions of North America have not shown signs of imminent danger, by understanding the habitat designs that impact these species, we can apply these findings to species in other geographic locations (Lacki et al. 1992).

The purpose of this study was to monitor wildlife use on mined sites of varying ages since disturbance and post-mining land uses at two locations in southwestern Virginia. Bird, salamander, and frog communities were sampled to gain an understanding of site use and species composition. This information was compared with wildlife communities on nearby mature reference forests to better understand the impacts of mining and reclamation.

Objectives

1. To determine avian and amphibian community composition of different age classes of reclaimed mine lands that have been restored to wildlife habitat and forest post-mining land uses.
2. Compare avian and amphibian communities of reclaimed wildlife habitat and forest communities to: (1) reference forests that have not been recently disturbed by mining or harvesting, and (2) forests that are regenerating after recent harvest.
3. Compare the structure and composition of reference forests to that of forests established on reclaimed sites, and compare the response of selected wildlife species to habitat patterns on reference and reclaimed sites.
4. Develop guidelines that can be used to suggest standards for reclaiming sites with forests that will meet avian and amphibian objectives.

Overview of Methods

- Field work was conducted in 2007 and 2008 at the Powell River Project (PRP) in Wise County, Virginia, and also on the Public Access Lands for Sportsmen (PALS) property owned and managed by The Forestland Group, LLC in Dickenson County.
- We sampled in 6 cover types: pre-SMCRA (mined prior to the Surface Mining Control and Reclamation Act, 1977), early successional, mid-successional, managed pastureland, reference, and recently harvested reference (Table 1, Figure 1).
- Bird point count surveys consisted of tallying all bird species and counting individuals during a 5 minute survey period. Each of 102 sampling points was visited 10 times over the course of 2 breeding seasons (May-July). All surveys were conducted between 6 and 9 AM on clear mornings with minimal winds.
- Bird presence was related to habitat characteristics on the ground, and to cover type data from Virginia Base Mapping Program (VBMP) aerial photography using logistic regression modeling.
- Two methods were used to sample salamander populations from May-August:
    - A series of wooden coverboards to act as artificial cover structures that provide habitat for salamanders.
    - Time constrained (20 minutes) night searches during rainy, humid evenings when salamanders would be actively foraging and generally visible on the surface.
- Frogs were sampled at water bodies on wet summer evenings using frog call survey methods from the North American Amphibian Monitoring Program (NAAMP 2009).

Table 1. Sampling point distribution across study areas (Powell River Project [PRP] and Public Access Lands for Sportsmen [PALS]) and land use classifications.

	Number of sampling points		
Land use classification	**PALS**	**PRP**	**TOTAL**
Early successional reclaimed (~5-12 years)	9	10	19
Mid-successional reclaimed (~13-25 years)	4	7	11
Harvested (1990-2005)	5	2	7
Managed pastureland	13	3	16
Pre-SMCRA (~30-60 years)	27	6	33
Mature forest (~65-100 years)	8	8	16
TOTAL	**66**	**36**	**102**

Figure 1. Representative photos of general cover type categories that were sampled. Photos were all taken at the PALS site.

A. Early successional

B. Mid-successional

C. Harvested

E. Pre-SMCRA

D. Managed pastureland

F. Mature forest

Summary of Results

Birds

Because distinct groups or guilds were identified through cluster analyses of habitat characteristics (Carrozzino 2009), habitat appears to be a good descriptor of relationships within the bird community on the study areas. These guilds that respond similarly to habitat characteristics can be managed as a group rather than trying to focus on individual species.

Mature forest species, such as Northern parula and wood thrush, responded to characteristics of undisturbed habitat, such as canopy cover and canopy height. Early successional species, such as American goldfinch and prairie warbler, required more open areas with scattered vegetation and small trees. Forest generalists (e.g., scarlet tanager and hooded warbler) and shrubland generalists (e.g. blue-winged warbler and yellow-breasted chat) were loosely associated with characteristics similar to those of the mature forest species and early successional, respectively. However, discrete or specific habitat characteristics were more difficult to identify, indicating a more "generalist" approach to habitat selection by these species.

Table 2. Representative bird species identified as part of four guilds during cluster analysis.
A=abundant; relative abundance > or = 0.4 birds observed per station per visit
C= common; relative abundance 0.2 - 0.399 birds observed per station per visit
R= regular; relative abundance 0.1 – 0.199 birds observed per station per visit
U= uncommon; relative abundance 0.01 – 0.099 birds observed per station per visit
+ = incidental; relative abundance < 0.01 birds observed per station per visit

	Early successional	Mid successional	Harvested	Pasture	Pre-SMCRA	Mature forest
Early successional guild						
Common yellowthroat	C	U		U	U	+
Eastern meadowlark	U	U		U		
Grasshopper sparrow	U	U		U		
Field sparrow	A	C		A	U	U
Prairie warbler	A	U	U	R		U
Mature forest guild						
Blue-headed vireo	+				U	R
Black-throated green warbler		U	U		R	U
Northern parula					U	U
Ovenbird		U	C		U	C
Wood thrush	U	U	R	U	U	R
Shrubland generalists						
American robin	U	U	U	U	U	+
Indigo bunting	A	A	A	A	A	C
Northern cardinal	R	R	R	R	C	R
White-eyed vireo	U	U	R		U	U
Yellow-breasted chat	A	C	A	R	U	R

Table 2. (continued)

	Early successional	Mid successional	Harvested	Pasture	Pre-SMCRA	Mature forest
Forest generalists						
Blue jay	+	U	U	U	R	U
Carolina chickadee	U	U	U	U	C	R
Dark-eyed junco					U	
Mourning dove	U	U	C	U	U	U
Scarlet tanager	+	U	R		U	R

Amphibians

Six species of salamanders were observed using cover objects and actively foraging on the surface. The species captured most frequently were red-spotted newt (39 captures) and slimy salamander (18 captures). Fifteen salamanders were found under cover boards, and all other observations were made incidentally or during night searches. Most salamanders were found in mature forest (42 captures) and on pre-SMCRA (21 captures) sites, with only one individual found in pine cover on a mid-successional reclaimed site (Table 3).

We identified 8 frog species during frog call surveys or when encountered while on site for other work (Table 4). Spring peepers were heard most frequently near water bodies and calling from wet highwalls. We often heard spring peepers in full chorus, where calls are constant, continuous, and overlapping. We also frequently heard bullfrogs and green frogs at a lower call intensity (i.e. individual calls could be distinguished).

Table 3. Salamander species encountered from May-August in 2007 and May-September 2008. Four cover types were searched: early successional reclaimed, mid-successional reclaimed, pre-SMCRA, and mature forest.

Species	Cover type	Total # of captures
Longtail salamander	Pre-SMCRA	4
	Mature forest	1
Northern red salamander	Pre-SMCRA	1
Red-spotted newt	Mid-successional reclaimed	1
	Pre-SMCRA	10
	Mature forest	28
Northern slimy salamander	Pre-SMCRA	5
	Mature forest	13
Southern two-lined salamander	Pre-SMCRA	1
Spotted salamander	Mature forest	0[a]

Table 4. Frog species identified at PRP from May-July 2007 and 2008.

Species	Both years	2007 only	2008 only
American toad	E[a]		
Bullfrog	1[b]		
Fowler's toad		1, 2	
Gray treefrog		E	
Green frog	1, 2		
Pickerel frog			1, 2, 3
Spring peeper	1, 2, 3		
Upland chorus frog		2, 3	

[a] "E" indicates that the species was encountered on site and not heard during call surveys.
[b] Indicates the North American Amphibian Monitoring Program call intensity score:
1= Individuals can be counted; there is space between calls.
2= calls of individuals can be distinguished by there is some overlapping of calls.
3= full chorus, calls are constant, continuous, and overlapping.

Conclusions

From our research, it is clear that a diversity of bird species can use reclaimed sites and the surrounding habitat during the breeding season. By identifying important habitat variables, we can customize the reclamation processes to fit the management goals for the property. For example, if managers are provided with information indicating that some Neotropical migrants prefer areas with conifers and small woody stems (e.g. common yellowthroat), these habitat characteristics can be provided or encouraged on reclaimed sites to attract the desired species. This type of active management will be particularly important to provide habitat for species of concern, such as the golden-winged warbler.

The methods developed in this study could be used to assess wildlife communities on reclaimed sites in other parts of the Appalachian region, and are adaptable to evaluating other forms of disturbed wildlife habitat. Long-term monitoring of these wildlife communities, along with vegetation and environmental considerations, will serve to further describe the restoration of reclaimed coal mines in Appalachia.

Although this work serves as a significant step to understanding wildlife use on reclaimed surface mines, data collected represent visual and auditory observations and do not include any information about reproductive success or survival. Without this important demographic information, we cannot fully relate the presence or density of species to the habitat quality on these sites (Van Horne 1983, Vickery et al. 1992). The cumulative value of these sites to birds will be best reflected by knowledge of reproductive success linked to population estimates. We plan to initiate a follow-up study to focus on avian survival and reproduction beginning in the spring of 2010.

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Appendix Key:

A=abundant; relative abundance > or = 0.4 birds observed per station per visit

C= common; relative abundance 0.2 - 0.399 birds observed per station per visit

R= regular; relative abundance 0.1 – 0.199 birds observed per station per visit

U= uncommon; relative abundance 0.01 – 0.099 birds observed per station per visit

+ = incidental; relative abundance < 0.01 birds observed per station per visit

Appendix. Relative abundance of 80 species observed at PRP and PALS in southwestern Virginia in 2007 and 2008, calculated as the number of observations per point per visit. A star (*) identifies a bird observed in 2007 only; a dagger (†) identifies birds observed in 2008 only.

	Land use classification					
	Early Successional	Mid-successional	Harvested	Pasture	Pre-SMCRA	Reference
Species	n=19	n=11	n=7	n=16	n=33	n=16
Acadian flycatcher *						+
American crow	U	R	U	U	U	U
American goldfinch	C	R	C	A	R	U
American kestrel *					U	
American robin *	U	U	U	U	U	+
American woodcock *					U	+
Barn swallow				U		
Black-and-white warbler	U	U	R	U	A	C
Black-billed cuckoo †	U				+	
Blackburnian warbler †						+
Black-capped chickadee				U	U	U
Black-throated blue warbler	U	U			U	U
Black-throated green warbler		U	U		R	U
Blue jay	+	U	U	U	R	U
Blue-gray gnatcatcher	U				U	
Blue-headed vireo	+				U	R
Blue-winged warbler	C	R	R	U	R	U
Brown thrasher	U	U		U		
Brown-headed cowbird	U	+	R	U		+
Carolina chickadee	U	U	U	U	C	R
Carolina wren	R	C	C	U	C	R
Cedar waxwing †	U		U	U	U	U
Cerulean warbler *		U	U			U
Chestnut-sided warbler †		+	U			U

Appendix. (continued)

Species	Land use classification					
	Early Successional	Mid-successional	Harvested	Pasture	Pre-SMCRA	Reference
	n=19	n=11	n=7	n=16	n=33	n=16
Chimney swift †				U		
Chipping sparrow	U	U	U	R	R	U
Cliff swallow †				+		
Common grackle *				+		+
Common raven †		+				
Common yellowthroat	C	U		U	U	+
Cooper's hawk *		U	U			
Dark-eyed junco †					U	
Downy woodpecker	U	U	U	U	U	U
Eastern bluebird	+	+		U		
Eastern meadowlark	U	U		U		
Eastern phoebe	U		U		U	
Eastern towhee	A	A	A	A	C	R
Eastern wood-pewee			U	+	+	U
European starling	+			C		
Field sparrow	A	C		A	U	U
Golden-winged warbler	U			+	+	+
Grasshopper sparrow	U	U		C		
Gray catbird	U	U	U		+	U
Hairy woodpecker				+	+	U
Hooded warbler	R	C	A	U	C	A
Indigo bunting	A	A	A	A	A	C
Kentucky warbler			U		+	+
Killdeer *	+					
Magnolia warbler *						U
Mourning dove	U	U	C	U	U	U
Northern bobwhite	U	U		U	U	
Northern cardinal	R	R	R	R	C	R

Appendix. (continued)

Species	Land use classification					
	Early Successional	Mid-successional	Harvested	Pasture	Pre-SMCRA	Reference
	n=19	n=11	n=7	n=16	n=33	n=16
Northern mockingbird*	U	+	U	+	+	
Northern parula					U	U
Ovenbird		U	C		U	C
Pileated woodpecker	+	U		U	U	U
Pine warbler	+	+			+	
Prairie warbler	A	U	U	R		U
Red-bellied woodpecker	+		U			
Red-eyed vireo	R	C	C	U	A	A
Red-headed woodpecker †					+	
Red-shouldered hawk*				+		
Red-tailed hawk						+
Red-winged blackbird	U	+		U	U	
Rough-winged swallow †	U					
Ruby-throated hummingbird	+		U	U	+	+
Scarlet tanager	+	U	R		U	R
Song sparrow	U	U		U		
Swainson's warbler †		+			+	U
Tree swallow	U			U		
Tufted titmouse	U	R	U	U	R	R
Veery †						+
White-breasted nuthatch			U		+	U
White-eyed vireo	U	U	R		U	U
Wild turkey		U		U	+	U
Wood thrush	U	U	R	U	U	R
Worm-eating warbler	U				+	
Yellow-billed cuckoo	U	U	U		U	U
Yellow-breasted chat	A	C	A	R	U	R
Yellow-throated vireo †					+	

Nesting Results and Habitat Assessment of the Nesting Box Trail for *Sialia sialis* (Eastern Bluebird) In the Powell River Project Education Center Year 3: Addition of Awnings to Open-topped Boxes

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Abstract

Awnings were added to the open-topped boxes during the 2009 breeding season along the bluebird nesting box trail at the Powell River Education Center to decrease daytime temperatures in the boxes by providing shade, while allowing in the elements to deter competitors. During the 2009 nesting season (late March to mid-July), nesting activity, as in the previous two season was limited to the closed top boxes. Bluebirds and chickadees were active in field 1 and successfully fledged young. Bluebirds and tree swallows were active in field 2, but none of the nests were successful in fledging any young. During this season, a total of nine bluebirds and fifteen chickadees were fledged; neither of the tree swallows nests were successful. Student volunteers from the Mountain Empire Community College assisted in monitoring the boxes and counting insect samples.

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[2]Mountain Empire Community College student volunteers.

Introduction

During the third year of the project along the bluebird trail established at the Powell River Education Center, open-topped boxes were modified by adding an awning to reduce the amount of sunlight that entered the boxes. The hypothesis behind the modification was that the addition of the awnings would reduce the internal box temperature (especially during the second half of the season) and make the boxes more attractive to the birds while maintaining the open box design. In addition to the attachment of awnings, the directions with respect to compass points that box openings faced were determined for each box. Student volunteers from Mountain Empire Community College monitored the nesting activity and analyzed insect samples. It was hoped that there would be increased nesting activity from the previous year in order to test for a preference in box design.

Methods

Nesting box preference- The objective of this study was to test whether bluebirds have a preference for the open or closed topped boxes. Each nesting box site consisted of two boxes. One box was the traditional design with the closed top (Figure 1a). The second box was the open topped design with an awning attached to block the sun while still allowing rain to enter the box (Figure 1b). This box design is similar to the design that was found to be successful in deterring competitors in a Wisconsin study (Bauldry, 1995).

Orientation of box openings were determined by compass. Dhondt and Phillips (2001) suspected that box preference would be affected by the prevailing direction of storms and for the avoidance of the afternoon sun.

a. b.

Figure 1. (a) Closed and (b) open topped nesting box with awning.

Boxes were monitored for activity on a weekly basis between March 31 and July 14, 2009 following the protocols established by the North American Bluebird Society (Fact Sheet: Monitoring Bluebird Nest Boxes, 2002) and the Virginia Bluebird Society (Virginia Bluebird Trail Monitoring Information, 2006). Data was recorded on forms provided on the Virginia Bluebird Society website.

Survey of insect and invertebrate populations. Insects and other invertebrates were sampled using passive pan traps, and insect nets along 30 m transects. Sample sites are indicated in figures 2 and 3. Pan traps were placed outside the fences to prevent injury to cattle. Transect sampling took place inside or along the fence lines. Pan traps consisted of 13 in x 9 in metal cake pans sprayed yellow to attract a large variety of insects (figure 5a; Terrestrial Arthropod Densities, 1994), and placed flush with the substrate. The pans were filled with a soap and salt solution, which acted as a trap and as a temporary preservative. The traps remained in place for seven days after which specimens were collected by pouring the contents of the pan though a strainer. The specimens were rinsed and placed in 95% ethanol. Animals were also collected along 30 m transects by sweeping vegetation with an insect net (figure 5b; Perry et al, 2001), and transferred to a jar containing 95% ethanol. Specimens were identified and sorted into groups using the National Audubon Society Field Guides to North American Insects and Butterflies.

Figure 3. Field 1: Nesting box sites indicated by numbers. Pan sample locations indicated by □'s. Transect locations indicated by dashed lines (----). Arrow indicates north. The B indicates the position of the barn. (Image from Microsoft Virtual Earth.)

Figure 4. Field 2: Nesting box sites indicated by numbers. Pan sample locations indicated by □'s. Transect locations indicated by dashed lines (----). Arrow indicates north. (Image from Microsoft Virtual Earth.)

a. **b.**

Figure 5. (a) Pan sample between boxes 5 and 6 after one week; (b) A. Russo collecting specimens along the 30 m transect line by boxes 8 A and B.

Results

Nesting activity: For a third year in a row, bluebirds, tree swallows, and for the first time black-capped chickadees limited their nesting activities to the closed top boxes (Table 1). The first bluebird eggs were found along the trail on April 9 in box 3A and 8A. Four additional eggs were laid in box 3A by the following week. Four of the five eggs hatched by May 7 and all of the chicks fledged by the time the box was checked on May 19. No additional activity was noted in the box the rest of the season. Two bluebird eggs were found in box 8A on April 9, but the eggs disappeared by the next week lost to an unknown predator. A single bluebird eggs was found in the nest on May 7; however, it was abandoned.

Box	Species	Nest building	# of Eggs	# of Hatchlings	# Fledged
1 A	CH,BB	complete	0	0	0
1 B	--	--	0	0	0
2 A	CH	complete	6	6	6
2 B	--	--	0	0	0
3 A	BB	complete	5	4	4
3 B	--	--	0	0	0
4 A	CH	complete	5	3	3
4 B	--	--	0	0	0
5 A	BB	complete	8	7	4
5 B	--	--	0	0	0
6 A	--	--	0	0	0
6 B	--	--	0	0	0
7 A	CH	complete	6	6	6
7 B	--	--	0	0	0
8 A	BB	complete	3	0	0
8B	--	--	0	0	0
9 A	TS	complete	5	0	0
9 B	--	--	0	0	0
10 A	TS	complete	5	5	0
10 B	--	--	0	0	0
11 A	--	--	0	0	0
11 B	--	--	0	0	0
12 A	BB	complete	6	5	0
12 B	--	--	0	0	0
13 A	--	--	0	0	0
13 B	--	--	0	0	0

Table 1. Nesting results for the 2009 nesting season. (A: closed top box; B: open top box; BB: bluebirds; CH chickadees; TS tree swallows).

Eggs were found in four boxes (2A, 5A, 10A and 12A) on April 28 . Six chickadee eggs were laid in 2A. These eggs later hatched and all the chicks fledged (figure 6 a). The eggs in box 5A were laid by bluebird; four of the five eggs hatched but only one of the hatchlings fledged. The cause of death was unknown; however, the net was infested with ants. There was a significant increase in the ant population in the sample collected near box 5A [142 ants in 2009 compared to 14 ants in 2008 (Burkart et al., 2008)]. Ants were a problem in many of the boxes along the fence line around both fields. When disturbed, the ants were highly aggressive. One investigator was bitten while doing maintenance on a box (A. Russo, per. comm.). Five tree swallow eggs were found in box 10A and successfully hatched, but were lost before the next monitoring to an unknown predator. A bluebird laid eggs in box 12A. All eggs hatched (figure 6 b), but the chicks were found dead on the May 12 monitoring trip. Cause of death was unknown, but it is possible that the parents were killed during a strong thunderstorm that moved through the area. On May 8, a long-lived supercell thunderstorm moved through Wise Co. causing the National Weather Service in Morristown TN to issue a tornado warning. It was later determined that an EF2 tornado touched down in the county around 9:45 pm EDT (National Weather Service Forecast Office, 2009).

a. **b.**

Figure 6. (a) Black-capped Chickadee nest containing chicks within days of fledging. (b) Bluebird nest containing two day old chicks. Note the difference in nests; bluebirds make a cup-shapped nest from dried grass while chickadees build a foundation of moss and make a cup of dried grass lined with fur and feathers.

On May 7, six chickadee eggs were found in box 7A, while one bluebird egg was found in box 8A. All six of the chickadee eggs hatched and successfully fledged, while the bluebird egg was abandoned.

Five chickadee eggs were present in box 4A on May 19. Only three of these eggs hatched and all nestlings fledged. Tree swallow eggs were found in box 9A on May 28, but were lost to an unknown predator by the next week.

The last nesting of the season was in box 5A. A female bluebird was actively sitting on the nest on June 24. The number of eggs was not determined at that time, because we did not want to chase the female from the nest. Three hatchings were later found in the nest and successfully fledged.

Insect and invertebrate survey: Insects and other invertebrates were sampled by two methods [insect net and pan trap (Tables 2 and 3)]. A total of 6681 specimens were identified. As in the previous years, the largest numbers of specimens were collected by the pan traps. Specimens were identified and placed into one of twenty-six invertebrate groups using Milne et al. (2005). In addition to the invertebrates, a salamander was collected in pan trap 6.

30 m Transects

Group	Field 1				Field 2	
Sample	1	2	3	4	5	6
Ants	0	1	0	0	0	6
Aphids	0	8	3	0	0	23
Bees	58	51	22	3	118	96
Beetles	9	29	3	2	39	72
Butterflies	0	3	0	0	3	2
Caterpillars	0	0	0	0	0	3
Centipedes	0	0	0	0	0	0
Crickets	17	1	4	4	17	12
Diplurian	0	0	0	0	0	1
Dragonflies	1	0	0	0	0	0
Earwigs	0	0	0	0	0	0
Flies	7	3	12	3	9	38
Grasshoppers	2	20	3	0	18	26
Lacewing	0	0	0	0	0	0
Leafhoppers	166	102	58	14	86	71
Long-legged seed bug	0	3	0	0	1	1
Millipedes	0	0	0	0	0	0
Mosquitoes	0	7	7	4	1	4
Moths	0	2	0	0	0	1
Mill bugs	0	0	0	0	0	0
Roach	2	0	0	0	0	0
Sawflies	0	0	0	0	0	0
Slugs	0	0	0	0	0	0
Snails	0	1	0	0	1	0
Spiders	13	25	24	3	16	49
Ticks	0	0	0	0	0	0
Wasps	2	3	3	2	4	2
Weevils	0	3	0	0	5	10

Table 2. Results of insect and invertebrate transect surveys conducted July 21 (field 1) and July 28 (field 2), 2009.

Pan Traps

Group	Field 1				Field 2	
Sample	1	2	3	4	5	6
Ants	29	49	142	17	28	30
Aphids	2	0	4	0	6	0
Bees	187	572	342	73	35	102
Beetles	20	39	55	29	64	27
Butterflies	2	2	2	6	10	0
Caterpillars	0	0	1	0	1	0
Centipedes	2	0	0	1	0	0
Crickets	7	40	31	13	19	28
Diplurian	0	0	0	0	0	0
Dragonflies	8	0	0	0	0	0
Earwigs	6	22	27	0	0	4
Flies	64	62	78	70	105	149
Grasshoppers	16	2	7	10	5	13
Lacewing	0	1	0	0	3	0
Leafhoppers	335	526	489	192	165	310
Long-legged seed bugs	0	0	0	1	2	2
Millipedes	0	0	0	0	0	0
Mosquitoes	78	15	6	2	1	3
Moths	0	25	27	0	0	7
Mill bugs	0	0	0	1	0	0
Sawflies	0	27	4	0	6	12
Slugs	11	2	19	4	0	0
Snails	0	0	0	0	4	5
Spiders	27	29	76	12	18	25
Ticks	0	0	4	0	0	0
Wasps	0	17	3	37	8	20
Weevils	0	0	0	0	6	0

Table 3. Results of insect and invertebrate pan surveys conducted between July 21 and 28 (field 1) and July 28 and August 4 (field 2), 2009.

Nesting activity and nesting box hole orientation: Box orientation according to the compass points was considered when the trail was setup; however, the final orientation of the boxes was determined by position of the wire on the post and the need to keep the boxes on the outside of the fence and away from cattle. Half of the boxes faced southwest, south-southwest or west-southwest (table 4). Three of the boxes faced south, and two boxes faced west. Boxes 6A and 6B were the only boxes that faced north, while the remaining boxes faced east, southeast and northeast.

Field 1		Field 2	
box	compass reading	box	compass reading
1 A	224°	9 A	240 °
1 B	224°	9 B	125 °
2 A	219°	10 A	286 °
2 B	219°	10 B	207 °
3 A	235°	11 A	245 °
3 B	235°	11 B	45 °
4 A	208°	12 A	170 °
4 B	220 °	12 B	170 °
5 A	180 °	13 A	86 °
5 B	180 °	13 B	175 °
6 A	347 °		
6 B	347 °		
7 A	268 °		
7 B	270 °		
8 A	236 °		
8 B	248 °		

Table 4. Nesting box hole orientation for the bluebird boxes along the Powell River Project.

Discussion: From the results of three seasons of nesting activity, it can be concluded that the bluebirds, as well as tree swallow and black-capped chickadees that nested at the Powell River Educational Center preferred closed topped nesting boxes over the open design. The addition of the awning to reduce sunlight and the internal temperature in the open topped boxes, especially during the latter half of the season, did not appear to make the boxes more attractive to the three species of birds. Nesting patterns at the various sites were not be strongly influence by the type of food found near each site; the preferred food items for bluebirds [beetles, butterflies, crickets, grasshoppers, leafhoppers moths and spiders (All About Birds- Eastern Bluebird, 2003)] made up between 49.9% and 57.3% of the groups present in the combined tallies at each sampling site.

The most successful boxes, as determined by clutches that resulted in fledglings, were oriented either directly south or somewhere between south and west (table 4). Dhondt and Phillips (2001) suggested that nests that did not get the afternoon sun and faced in the opposite direction of prevailing storms had the highest fledging rates. The most successful boxes, with the exception of box 7A, did not face directly west. This box was shaded from the direct rays of the afternoon sun by a strand of pine tress. In addition, the most successful boxes were facing away from the storms that come in from the northwest out of Kentucky.

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Long-Term Mine Soil Weathering and Treatment Effects: Do Topsoil Substitutes Really Mimic Natural Soils?

2008/2009 Powell River Project Annual Progress Report

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Introduction and Background

The Surface Mine Control and Reclamation Act (SMCRA) of 1977 contained a number of contentious provisions including return to original contour (AOC), long-term liability bonding periods, and return to "equal or better" post-mining land use conditions. However, one of the more stealthy provisions was SMCRA's allowance for use of pre-selected overburden materials as topsoil substitutes when (A) the native A+E horizon materials are less than 6 inches thick, and (B) the physical and chemical properties of the proposed substitute spoil materials are deemed suitable for such use. Since native topsoil layers throughout the Appalachian coalfields are usually less than six inches thick, and removing them from steep slopes is difficult and expensive, the vast majority of coal mined lands in the region have employed topsoil substitutes.

In 1982, the USDI Office of Surface Mining and the Powell River Project co-funded the installation of the Controlled Overburden Placement (COP) experiment to objectively assess the viability of the topsoil substitute concept and to determine whether or not organic amendments would be beneficial. In one component of the COP experiment we are directly comparing five mixes of sandstone:siltstone (SS:SiS) overburden while in a separate experiment we are following the effects of topsoil return, sawdust addition and four incremental loading rates of biosolids. All treatments are replicated four times and the plots are split between herbaceous (dominantly tall fescue) and forest (red oak following pine) vegetation. We intensively monitored those two side-by-side experiments through the late 1980's, and our results can be reviewed at the PRP web site and at http://www.cses.vt.edu/revegetation/minereclam.html. In summary, we found that (A) properly selected and placed spoil materials provided an outstanding soil medium for tall fescue production and allowed vigorous invasion of native herbaceous species; (B) higher pH spoils such as the siltstone strata employed were deleterious to pine tree growth; and (C) higher rates of biosolids amendments drove high fescue production while suppressing the pines. The COP experiment remains the longest intact and continuously monitored study of mine soil genesis in the World. Follow-up studies by our group at other sites in the 1990's and early 2000's also characterized the wider effects of biosolids applications and the nature of inherent variability in mine soil properties in the Research & Education Center. However, very little detailed soil analyses have ever been performed on the native pre-mining soils in the Research & Education Center area for direct comparison.

Over the past decade, the concept of topsoil substitution has been directly and indirectly criticized from a number of perspectives. First of all, advocates of the return of Appalachian mined lands to native forest covers have pointed to the lack of topsoil salvage and the inclusion of higher pH unweathered spoils as directly inhibiting effective reforestation. These objections have been raised by citizens and certain well-trained scientists alike. Secondly, the fact that relatively unweathered spoils (such as those employed in the COP study) release significant total dissolved solids (TDS) loads to drainage waters over time has been implicated as a component of mining related surface water degradation under both low and moderate pH conditions. In fact, it now appears that mining discharges will be directly regulated for TDS over time and reducing bulk TDS may be a much more difficult water treatment proposition for the coal industry than limiting more conventional parameters such as total Fe and Mn. Finally, the ability of these mine soils to accumulate organic matter, maintain a stable and viable microbial biomass and available nutrient pools, and overall productivity potentials beyond the requisite five-year performance liability period is also questioned by many citizens' groups.

In 2007, we proposed to directly address a number of these challenges by initiating a new program of mine soil sampling and analysis utilizing our established baseline experiments at the Research and Education Center, and at other locations where long-term baseline data sets are available, that will allow us to study changes in mine soil properties and productivity relationships over prolonged periods of time. Furthermore, we will directly compare mine soil properties for a range of important parameters (e.g. pH, organic matter content, P-forms, microbial biomass) with a suite of unmined native soils forming out of the same rocks. Thus, by a combination of direct and differential analysis, we propose to meet the following objectives:

Research Objectives

1. To determine the long-term (20+ years) effects of overburden rock type and surface treatments on important mine soil morphological, physical, chemical and microbiological properties.

2. To directly compare the properties of weathering mine soils of varying age with unmined native soils formed from the same strata.

3. To measure the net TDS elution potential of a range of fresh, partially weathered and well-weathered topsoil substitute materials.

4. To predict the ability of selected overburden materials to weather and transform into mine soils suitable for the support of native hardwoods and hayland/pasture vegetation, and to estimate the rate of transformation.

Methods and Procedures

Overall Approach

We are fortunate to have an array of well-characterized, documented and "preserved" research sites throughout the Powell River Project Research & Education Center area and the surrounding region. These include the COP experiment, areas to the north of Powell River that have been minimally disturbed since 1990, and certain limited locations south of Powell River that have not been re-mined since 1990. While much of the 1990 aged mine soil surface received a uniform treatment of biosolids+compost, there are significant areas of that surface that did not. By differentially sampling across these contrasting treatment areas, we will be able to directly determine the net effect of organic matter additions on long term soil development process and important mine soil productivity parameters.

Furthermore, the recent re-mining activity to the south of Powell River will allow us to sample and “pair up” mine soil pedons that are very young (1 to 10 years) with much older mine soils (25+ years) to the north that formed out of identical parent materials. Finally, we also have access to a range of relatively intact native forest soils in the overall Powell River area that occur between mining disturbances.

We are now completing the second year (of three) of this study. In years one and two, we focused field work on collecting a wide range of unweathered and weathered spoil types in the region and on sampling pedons within the immediate vicinity of the Research & Education Center as described above. In the laboratory we focused on characterizing the chemical and physical properties of these soils, as well as on column leaching studies to characterize the potential leaching behavior of various mine spoil materials. In the upcoming final year, we will complete all laboratory work, sample or re-sample additional pedons to fill out the data set, and construct a qualitative model of how basic mine soil morphological, chemical, physical and microbiological properties respond to (A) initial spoil type and (B) initial surface treatments over extended periods of time.

For all soil pedons sampled in the area of the Research & Education Center and beyond, each morphological horizon and selected depth increment samples will be analyzed for the parameters listed below. Archived samples from 1981 and 1990 for matching pedons will be similarly analyzed, allowing us to determine both the mass leaching that has occurred over time within pedons and the net amount lost over 15 to 25 years.

pH and total titratable acidity
Saturated paste electrical conductance (EC) and solid salts species (cations + anions)
Total organic carbon (TOC) and Walkley-Black organic matter (OM)
Organic matter fractions
Microbial biomass
Bulk microbial activity (incubation/CO_2 evolution)
Total-P and Total-N
Exchangeable cations
Dilute acid extractable nutrients and metals
Extractable Fe and Mn oxides
Total-S and S-forms if $S \geq 0.2\%$
Calcium carbonate equivalence (CCE)
% Rock fragments
Particle size analysis
Aggregate stability
Moisture desorption/water holding capacity on < 2mm fractions

Progress to Date (August 2009)

Our efforts during the second year of this study have focused on 1) continued work in the field and laboratory to describe, sample, and characterize soil profiles developed in both undisturbed materials and in various spoil types, and 2) conducting leaching column studies to characterize the potential leachate characteristics of various mine spoils. Our column leaching studies have focused on detailed characterization of TDS elution with time and ionic species composition.

Soil Profiles

In the first year of this study ten soil profiles, including 3 unmined native soils and 7 mine soils, were described and sampled in the field. In year two an additional 2 mine soils were described and sampled, and several of the soil characterization procedures (listed above) were completed in the laboratory.

One objective of our study is to compare the properties of unmined native soils with weathering mine soils formed from the same strata. As an example, Tables 1 and 2 provide some chemical and physical data for a native soil and a mine soil which both formed from Taggart sandstone. These two soil profiles are illustrated in Figure 1. Although a deeper profile was exposed for the mine soil, the thicker solum of the native soil (51 cm vs. 24 cm) was readily apparent. The surface horizons (A and ^A1) of the two soils were similar in terms of depth, color, pH, CEC, TOC, and water holding, while their most notable differences included 1) texture (<2 mm) was coarser in the native soil, 2) rock fragments were more abundant in the mine soil, 3) EC was higher in the mine soil, and 4) extractable nutrients, with the exception of K and Fe, were higher in the mine soil. These differences, with few exceptions, were observed throughout the subsoil horizons as well. Of particular note, the pH of the parent material in the mine soil (pH > 5.4) was noticeably higher than that of the native soil (pH < 4.6).

Table 1. Some chemical properties of a native soil (PRP-2) and a mine soil (PRPS-5) formed from Taggart sandstone at Powell River Project.

horizon	EC	pH	N	C	CEC	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
	dS/m		%	%	cmol+/kg	------------------------- mg/kg -------------------------								
PRP-2 (native soil developed over Taggart sandstone)														
A	0.09	4.60	0.23	4.70	20.70	6	83	248	46	1.5	19.4	0.6	86.9	0.1
Bw	0.06	4.39	0.03	0.71	13.26	2	40	44	14	0.4	5.5	0.3	26.8	0.1
CB	0.05	4.49	0.03	0.48	6.82	2	49	46	22	0.3	2.5	0.3	23.0	0.1
C	0.04	4.57	0.03	0.36	10.78	2	47	59	49	0.4	3.0	0.3	24.6	0.1
PRPS-5 (mine soil developed from Taggart sandstone spoil)														
^A1	1.36	4.65	0.31	4.44	21.91	27	76	1062	280	3.5	28.7	0.8	31.0	0.3
^Bw	0.18	5.81	0.05	1.26	10.42	47	35	744	264	1.9	13.2	2.0	30.1	0.1
^2C	0.15	5.84	0.18	6.54	33.92	10	34	1894	506	5.4	14.0	0.5	8.3	0.1
^3C	0.13	5.46	0.01	0.31	4.74	2	31	249	120	0.6	12.5	0.4	23.3	0.1

Table 2. Some physical properties of a native soil (PRP-2) and a mine soil (PRPS-5) formed from Taggart sandstone at Powell River Project.

horizon	> 2mm	sand	silt	clay	water holding capacity	
	-------------------- % --------------------				-0.03 MPa	-1.5 MPa
PRP-2						
A	8.5	64.0	23.4	12.6	23.13	7.52
Bw	19.0	67.2	21.1	11.7	14.26	4.80
CB	10.5	65.3	23.4	11.3	14.20	4.53
C	14.0	65.0	25.6	9.4	15.43	6.31
PRPS-5						
^A1	47.3	49.4	35.5	15.1	21.39	8.10
^Bw	52.2	45.4	40.8	13.8	20.33	7.34
^2C	36.1	38.3	43.7	18.0	21.13	7.63
^3C	34.7	74.5	15.5	10.0	18.63	6.69

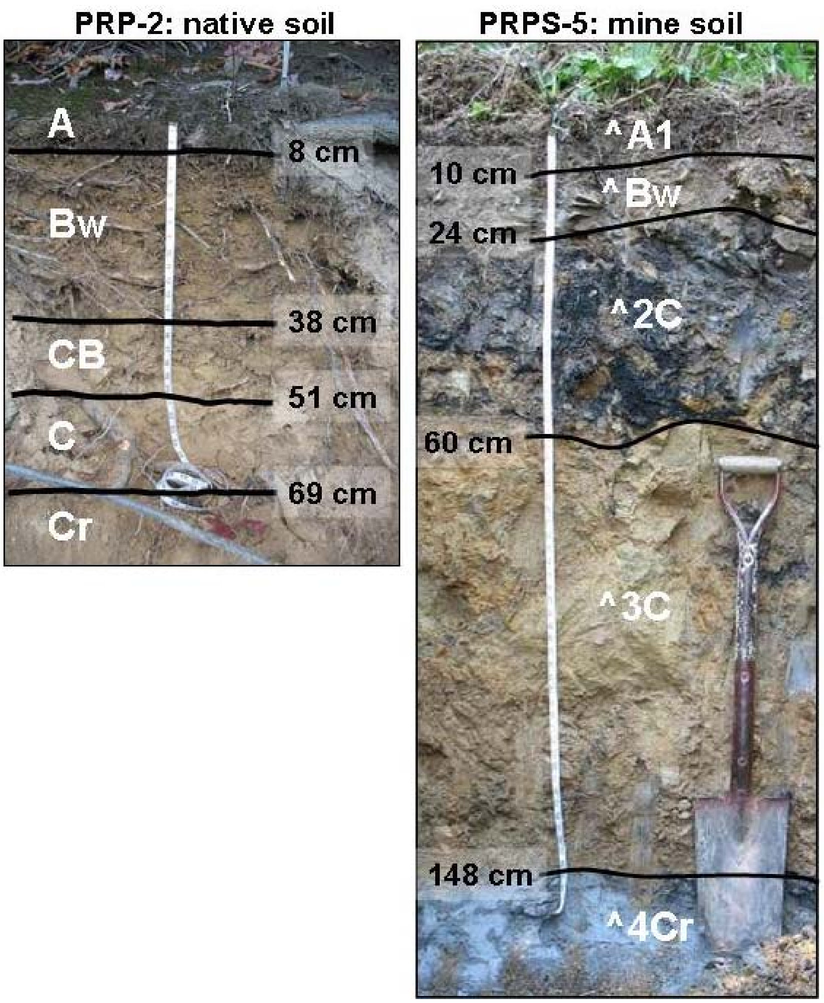


Figure 1. Two soil profiles - a native soil (PRP-2) and a mine soil (PRPS-5) - formed from Taggart sandstone at Powell River Project.

Spoil Characterization and Leaching/Weathering Trials

In year one of this study, fifteen samples representing fresh, partially weathered and well-weathered topsoil substitute materials were collected from PRP and other mines in southwest Virginia and eastern Kentucky. These samples represented a variety of spoil types including sandstone, siltstone and mudstones in different proportions and at various degrees of weathering.

A leaching column study was established in July 2008 to characterize bulk TDS and specific elemental release from a subset of the spoil materials. Three spoil samples (OSM 2, OSM 3, and OSM 11) were selected to represent a mudstone, a sandstone, and a mix of materials. Some geologic, chemical and physical characteristics of these three samples are presented in Tables 3 and 4. The leaching columns were built from PVC pipe with a diameter of 7.6 cm and a length of 40 cm (volume = 1200 cm^3). The samples were run in triplicate under saturated and unsaturated conditions (18 columns total), and were leached and sampled twice a week for 8 months using a simulated rainfall solution (pH 4.8). Leachate solution samples were analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), total organic carbon (TOC), cations, metals, Cl and SO_4.

After the first leaching study was completed (March, 2009) the columns were re-established in an identical manner as described above with a second set of spoil samples to more completely represent the various spoil types at various degrees of weathering. These columns are being leached and sampled twice a week using the simulated rainfall solution, and the leachate samples are being analyzed for pH, EC, and selected cations and metals.

From the first leaching study, the plotted data for EC and TDS (Fig. 2) were nearly identical other than the scale of the y-axis. The major difference between the two parameters was that EC was determined on the bulk unfiltered leachate sample and TDS was determined on a filtered sample with corresponding possible reduction/changes in the solution composition. As indicated in Figure 2, all three spoil samples experienced an initial TDS flush ranging from approximately 750 to >4000 mg/L. Leachate EC and TDS from the unweathered mine spoil (OSM #2) was consistently higher than from the partially oxidized and weathered samples. Initial values dropped quickly to a steady state of relatively low levels for the remainder of the leaching trial. No treatment effect of saturated versus unsaturated conditions was observed. The high correlation coefficient of r=0.98 between EC and TDS is not surprising, and underpins the regulatory assumption that EC can be used as an effective proxy for TDS.

The large elution of bulk EC and TDS from the mudstone spoil probably reflects the presence of a highly reactive sulfide (framboidal?). Although present in relatively low amounts (0.23% S), the sulfides reacted quickly with substrate carbonates to produce sulfates and prolonged sulfate release over the extent of this experiment. Acid-base reaction control on leachate chemistry was also reflected in leachate bicarbonate and sulfate as discussed below.

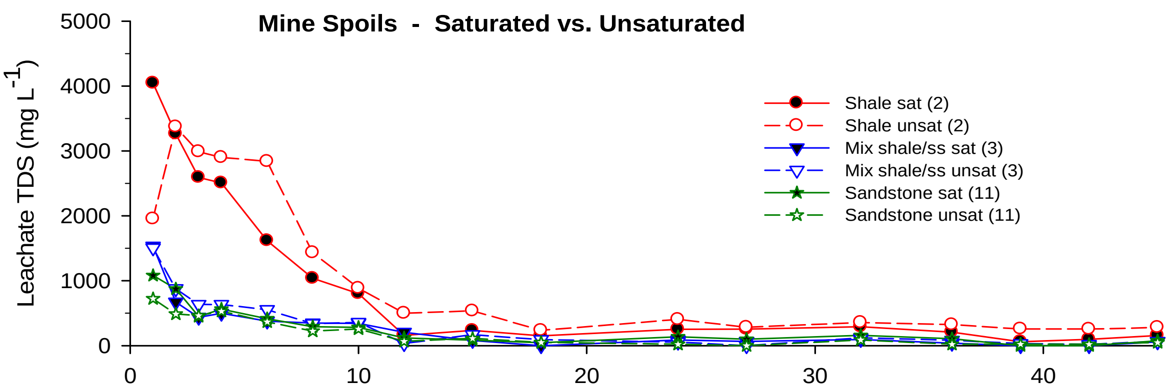
Table 3. Geologic description of topsoil substitute materials.

Lab-ID	Geologic Description	Coal Seam
OSM 2	93% dark gray, carbonaceous, silty mudstone; 6% unweathered, gray, fine-grained sandstone and siltstone; 1% coal.	Hazard #7 and #8
OSM 3	50% highly weathered, gray and orange, fine grained and medium to coarse grained, feldspathic sandstone; 30% unweathered, gray, silty mudstone ; 10% unweathered, feldspathic sandstone; 8% unweathered, gray, silty mudstone; 2% coal.	Kelly/ Imboden
OSM 11	99% weathered sandstone; 1% silty mudstone; trace coal.	Taggart

Table 4. Some chemical and physical characteristics of topsoil substitute materials.

Lab-ID	<1 cm	>1 cm	pH	EC	PPA[1]	CCE	S	C
	-------- % --------			dS/m		%	%	%
OSM 2	60	40	7.0	3.48	0.00	4.6	0.23	4.73
OSM 3	87	13	6.9	0.94	3.58	1.3	0.07	3.25
OSM 11	68	32	6.3	0.56	0.28	3.7	0.02	0.78

[1] PPA = Peroxide Potential Acidity: results expressed in tons of $CaCO_3$ lime demand per 1000 tons material.



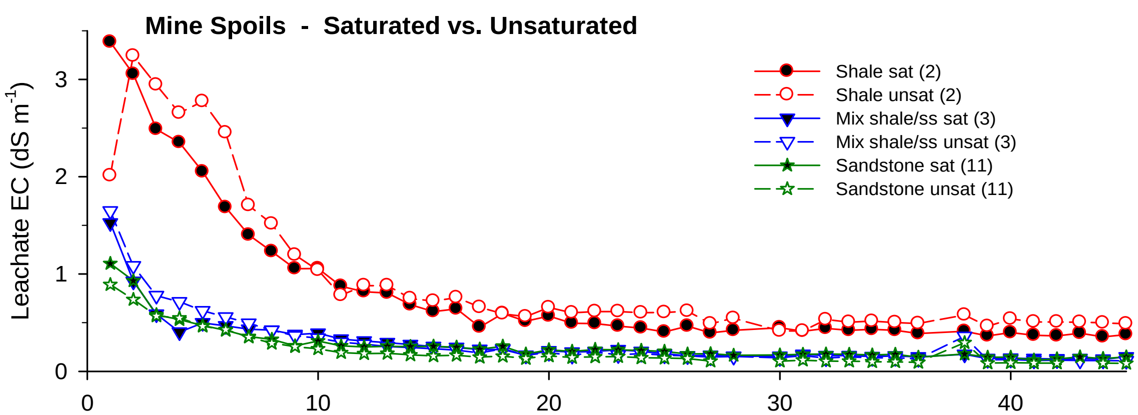


Figure 2. Leachate TDS from three mine spoils under saturated and unsaturated conditions. The 45 leachate events occurred over 153 days.

The relationship of leachate TDS to its mass elemental composition (mg L^{-1}) was evaluated periodically during the leaching period. Examples of these data are graphically presented in Figure 3. Six elements, Ca, K, Mg, Na, S, and C were found to be either quantitatively and/or functionally the major components of the leachate solutions. In all but one instance, the sum of the elements in the leachate solution exceeded the TDS values, and was likely due to methodological (filtering) differences. We believe that the mass leachate concentrations probably contained colloidal suspended phases allowing the sum of elements to exceed TDS typically in the range of 20 to 40% (approached 90% for certain samples not shown here).

The elemental composition from the three samples under saturated conditions was dominated by sulfate and bicarbonate (Figure 3). The sulfate component decreased over the course of the leaching trial while the bicarbonate component remained approximately the same in mass, and thus became the dominant anion. The release of bicarbonate for OSM-2 under unsaturated conditions was approximately equal to that under saturated conditions. For the other two mine spoils, however, the elemental composition was dominated by the elution of sulfate, and bicarbonate was nearly absent due to acid neutralization reactions. The release of all other elements, which contributed only minor amounts to TDS, was very similar under saturated and unsaturated conditions.

The TDS x ion species data and insights summarized here are drawn from a much larger data set that is currently under review and will be reported fully in next year's final report. We are also currently analyzing additional mine spoil samples in the laboratory to expand the data set. However, we can make the following preliminary conclusions about TDS elution over time from these materials.

The mine spoils sampled in this study were typical of surface mined overburden in the central and southern Appalachians in that they were largely non-acid forming and moderate (> 6.0) in initial pH and prolonged leachate pH effects. Mine spoils that were significantly pre-weathered were lower in pH and Ca as expected. The samples appear to represent a broad range in elemental content, yet they did not include extreme values for any of the elements analyzed.

Due to their relatively high carbonate content (CCE), the majority of samples tested maintained a moderate pH (6.0 to 8.0) in leachates over the full study period (22 weeks). However, all samples eluted considerable levels (> 500 mg L^{-1}) of TDS (with high EC) over their initial leaching cycles and samples that contained significant reactive sulfides continued to elute high TDS levels for the duration of the study, regardless of their leachate pH values. However, prolonged and significant TDS release was observed from a mudstone spoil from Kentucky (saturated and unsaturated), and relatively high initial release occurred from one mixed mine spoil from Virginia. These differences in TDS release were all clearly related to basic sulfide oxidation reactions with subsequent generation of sulfate and other reaction and dissolution products.

This study also generated full leaching data sets on As, Mo, Se and several other ions of emerging regulatory interest which will be reported in full in next year's research report.

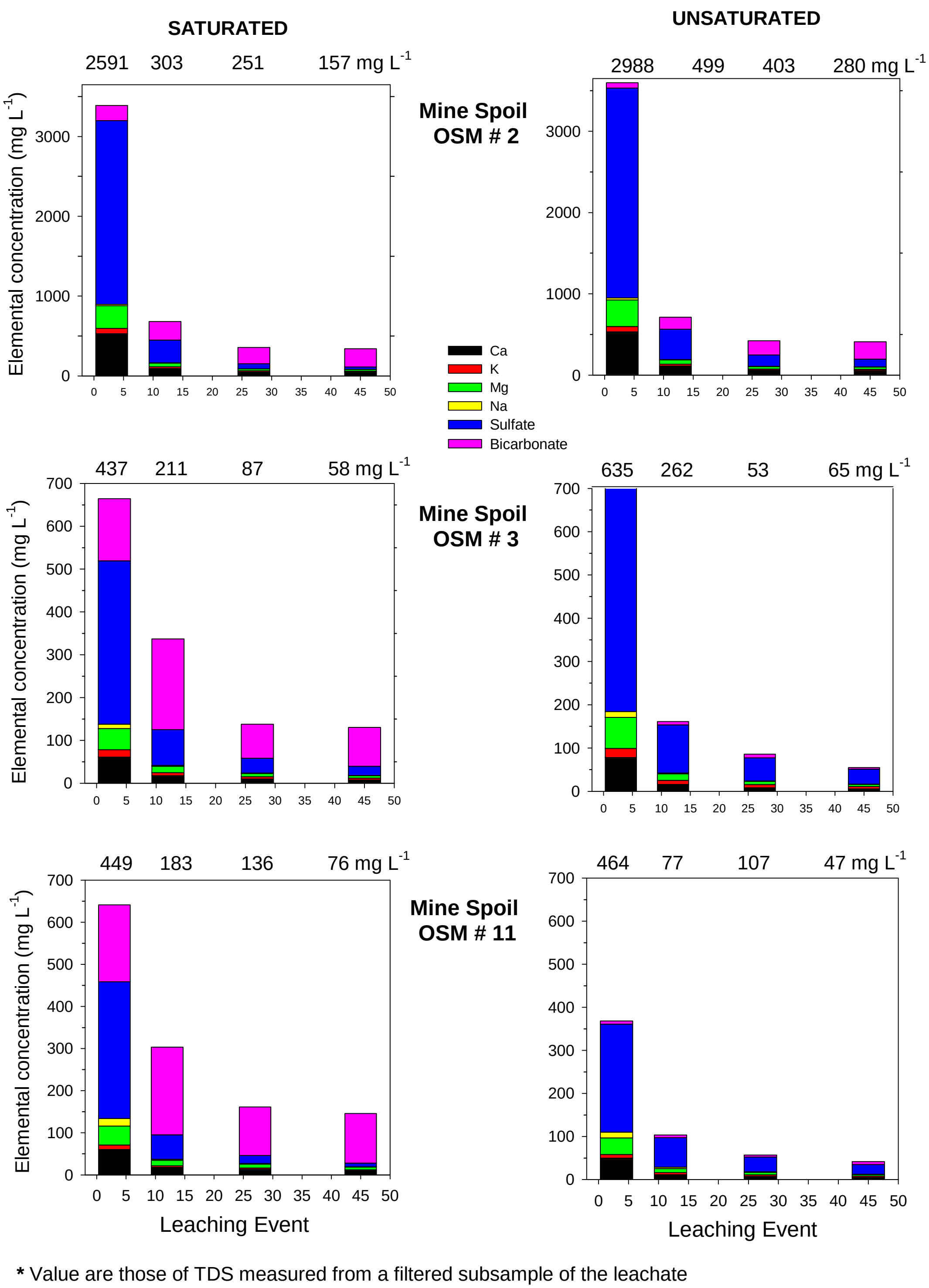


Figure 3. Quantitative distribution of major elements in leachate solutions and the respective TDS values from mine spoil. Samples represent leaching events # 3, 12, 27, and 45. Values within charts represent total leachate analyses while TDS value is given at top of charts.

Summary Work Planned for Year 3

In year 3, we will complete the remaining column leaching studies described above for an additional set of mine spoils from SW Virginia of varying lithologies and weathering/oxidation extent. We will also complete sampling and laboratory analyses of the 25+ year old mine soils from the COP experiment and compare their bulk physical and chemical properties with those of the original spoil samples taken from the plots in 1982.

Data Analysis, Synthesis and Expected Results

At the end of year three (2009/2010), we will be able to directly determine and report the relative effect of rock type and surface treatments in the COP experiment on 25 years of mixed herbaceous vegetation and tree growth. We will also be able to contrast the differential effects of the two different vegetative cover conditions on surface soil properties. Similarly, by comparing the properties of the biosolids treated/untreated 15 year-old Taggart mine soils, we will be able to confirm overall rates of important mine soil transformation such as pH reduction and organic matter accumulation in an initially high pH sandstone system. By the comparing the bulk salt and acid extractable nutrient+metal data for each pedon with depth, we will be able to calculate the mass “TDS leaching potential” of each mine spoil material and assess how much of the TDS load appears to have leached over 15 and 25 year time spans and from what depth. These data and findings will be reinforced by our spoil leaching column trials which were originally established in 2008 and are being continued with a new set of spoil samples for at least six months into early 2010. Finally, we will directly compare and contrast all mine soil pedons with nearby natural soils over the same strata.

At the completion of the study, we will integrate all data sets from all components of the study to specifically address and meet our first three objectives. The latter part of the final project year will be focused upon constructing a qualitative (but well quantified!) model of how SW Virginia mine soil properties change with time, and the relative effects of original spoil type and surface treatments on those processes.

Effects of Total Dissolved Solids in Streams of Southwestern Virginia

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Background and Approach

Total dissolved solids (TDS) are the inorganic salts, organic matter, and other dissolved materials in water. Elevated TDS can be toxic to freshwater animals by causing osmotic stress and affecting the osmoregulatory capability of organisms (McCulloch et al. 1993). Several prior studies have concluded that toxicity of TDS is a function of the solution's ionic composition as well as the TDS concentration (Goetsch and Palmer 1997, Mount et al. 1997; Clements 2002; Goodfellow 2000; SETAC 2004; Kennedy et al. 2005) and organism sensitivity.

Under the Clean Water Act, water quality criteria are components of water quality standards. As defined by the Code of Federal Regulations, criteria are "… elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use" [40 CFR 131.3(b)]. All Virginia waters are required to support a designated use defined by Virginia Department of Environmental Quality (DEQ) as "the propagation and growth of a balanced, indigenous population of aquatic life" (Virginia DEQ, 2007).

In 2006, Virginia DEQ initiated an evaluation of the potential to establish water quality standards for TDS as a response to total maximum daily load (TMDL) studies of streams draining watersheds affected by mining in southwestern Virginia (Maptech Inc 2004, 2005a, 2005b). Based on this evaluation, DEQ decided to proceed with an evaluation of the potential to establish a TDS water quality criterion.

Virginia DEQ currently uses a multimetric benthic macroinvertebrate community index, the Stream Condition Index (SCI), as its basis for water-quality assessment of benthic macroinvertebrate data (Burton and Gerritsen 2003; Virginia DEQ 2006). This research is using the Virginia SCI (VSCI) to evaluate TDS and/or component ion effects on benthic macroinvertebrate communities. Research goals are (1) to develop a database comprised of TDS-SCI relationships, and associated attributes such as habitat metrics, for freshwater streams that can support a recommended TDS criterion; and (2) to define relationships between TDS and/or component ion concentration levels and the VSCI.

Research Methods

1. Identify freshwater stream research sites that have elevated (i.e., above reference or background) TDS concentrations but appear to be otherwise relatively unaffected by non-TDS stressor effects.

   Research sites are being identified in consultation with VDMME, Virginia DEQ, and other cooperators. Virginia DMME databases are being accessed to identify streams draining current or former mining sites where TDS concentrations are elevated relative to background. GIS analyses, aerial photography and/or satellite imagery, and DEQ/DMME point-source discharge databases are being used in an effort to identify those high-TDS sites where non-TDS stressors do not appear to be present. Each potential site is visited to verify conditions.

2. Identify freshwater stream research sites that can serve as unstressed reference locations.

   These research sites are being used as reference sites for comparison with TDS-affected sites. Reference streams are selected based on similar geology and topography to the applicable non-reference streams in an effort to isolate TDS and the benthic population as the variables.

3. At each research site, sample benthic macroinvertebrates.

   Sampling is being conducted during the spring and fall benthic macroinvertebrate sampling seasons under baseflow conditions, avoiding time periods immediately following potentially scouring stormflow events, using Virginia DEQ biological monitoring procedures, which are similar to those described in Barbour et al (1999). DEQ biological monitoring personnel were consulted to assure comparable procedures. Benthic macroinvertebrate samples are identified to the genus/lowest practicable level with the exception of midges, which are identified to the tribe level

4. Characterize non-TDS stressor and other benthic macroinvertebrate community influences at all research sites by sampling habitat elements and water quality.

   A complete physical habitat assessment is being conducted at each sampling site according to protocols described in Barbour et al. (1999). Parameters characteristic of low-gradient streams like channel sinuosity, pool variability, and pool substrate characterization have been excluded.

   Water quality at each site is characterized at the time of benthic macroinvertebrate sampling for field parameters (pH, conductivity, temperature, dissolved oxygen) using a portable multi-probe sampler, major ions (Ca, Mg, K, Na, Cl, Sulfate), total dissolved solids, and metals (including Cu, Zn, Mn, Se, Al, Fe). Samples for metals analyses are field filtered. Inductively coupled plasma emission spectrometry (ICP) is used to measure dissolved Ca, Mg, K, Cu, Zn, Mn, Se, Al, Fe (APHA 1998). Ion chromatography (IC) is used to measure chloride and sulfate; TDS is measured via field filtration followed by drying at 180°C; and total alkalinity is measured via titration with standard acid, from which CO_3^{2-} and HCO_3^- are calculated.

5. Analyze data to determine relationships between TDS and VSCI.

   The VSCI will be the biotic indicator used to define an impairment threshold for use in data analysis. The impairment threshold used by Virginia DEQ (VSCI < 60) will be used in this study.

   The influences of TDS and component ions on the biotic indicator metric scores will be determined through a multiple regression approach. Component ion concentrations will be expressed on relative scales by summing all major cations and anions separately and expressing each component-ion concentration both as a percentage of the cation/anion concentration total and as a concentration. In this multiple regression procedure, the VSCI will be the dependent variable and (relative-) concentrations of component ions will be the independent variables. In this procedure, potential multicollinearity effects of component ion concentrations and TDS will be controlled.

Progress to Date

To date, 201 sites have been considered as candidates for study. This includes 22 potential reference sites and 179 potential test sites with elevated TDS that may meet the selection criteria. Of those 201 candidates, 148 have been visited and evaluated for inclusion in the study during site reconnaissance efforts to date. The visited sites were evaluated based on factors such as water quality, habitat quality, flow status, upstream landuses, and accessibility. Site information was reviewed to determine the best candidates for study. The 21 sites that were optimal for study were retained as primary candidates for sampling. Additional sites that met criteria but were less than optimal for study (e.g., unreliable access, marginal flow status, etc.) were reserved as secondary candidates for sampling. Table 1 presents a summary of reference and test site candidates, visited sites, those retained for study, and those sampled during Spring 2009.

Table 1. Site Selection Status as of July, 2009

Status	Ref	Test	Total
Candidate Sites	22	179	201
Sites Visited	8	140	148
Retained 1° Sites	3	18	21
Sampled Spring 2009	3	17	20

Figure 1 illustrates locations of the candidate reference and test sites visited and indicates which sites were retained as primary sites.

Figures 2-4 present photographs of typical reference and test site habitat.

Significant challenges remain in finding suitable sites. Much of Virginia's coalfield region has been developed for commercial, industrial, or residential purposes, with little public land remaining. Locating study sites free from residential or urbanization influences requires exclusion of nearly all streams larger than 2nd order. Finding suitable riparian and instream habitat becomes the next hurdle in the site selection process. Many of the remaining 1st and 2nd order streams have good forested riparian zones, but exhibit excessive sedimentation or substrate embeddedness, likely caused by legacy strip mining. Others have poor riparian vegetative zones, dominated by herbaceous species with little or no canopy over the stream channel. Additionally, regional seasonal dry conditions have led to many dry or nearly dry stream channels, even for some large 3rd order streams. One variable of influence that was not foreseen at the outset of this study is the relatively rapid and extensive proliferation of oil and natural gas wells and their associated access roads. The contribution of oil and natural gas well activities to stream sediment loads, while not currently quantified, is nonetheless a potential stressor to overall biological condition.

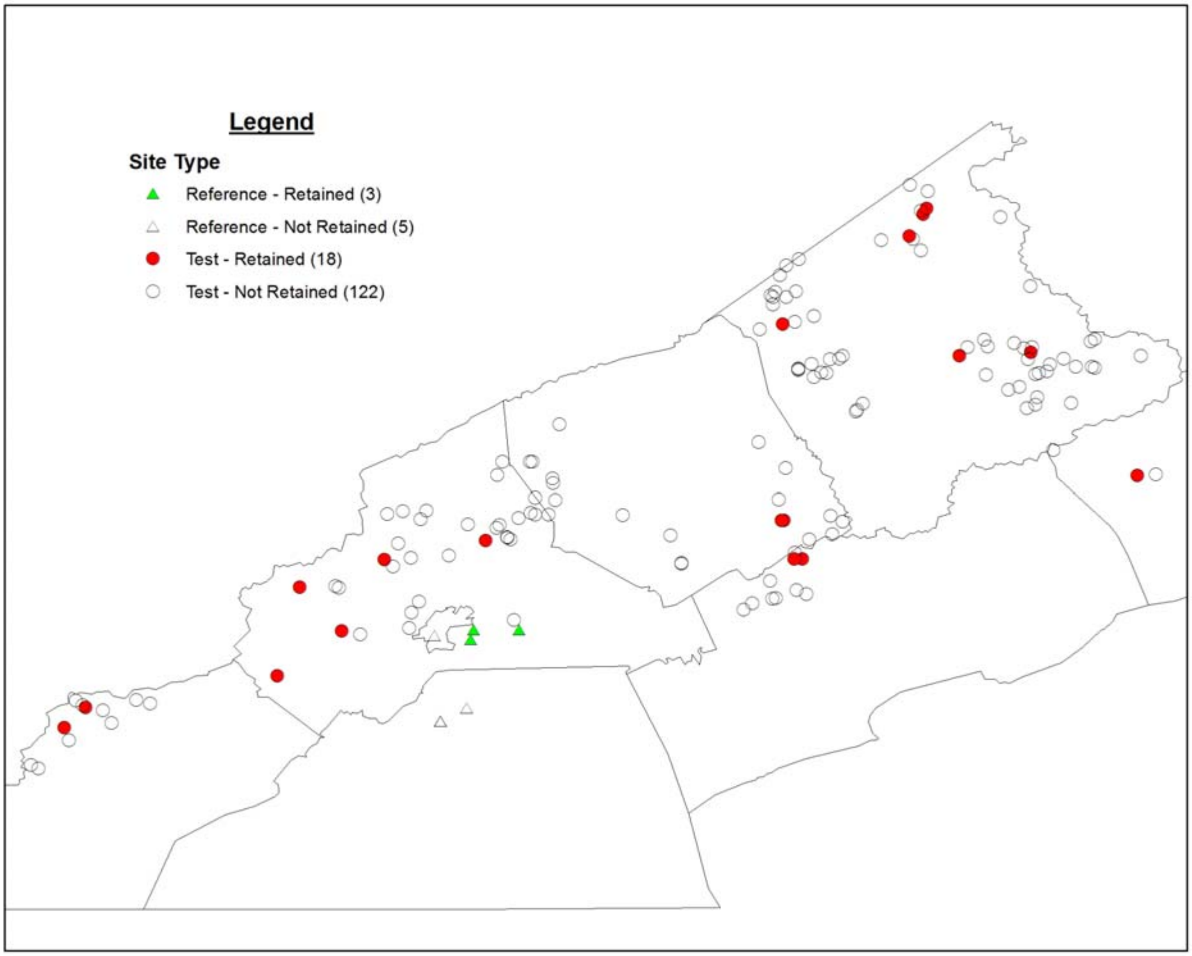

Figure 1. Sites Visited and Primary Sites Retained.

Data Summary

Three reference sites and five test sites were sampled for water chemistry and benthic macroinvertebrate populations in Fall 2008, and three reference sites and 17 test sites were sampled for water chemistry and benthic macroinvertebrate populations in Spring 2009. Tables 2 – 7 summarize data collected to date.

Schedule and Future Plans

Full-time activities were initiated in late July, 2008. The plans for the next four months (September-December, 2009) include evaluation of additional sites, sampling, sample processing, and taxonomic certification. The 20 sites from Spring 2009 will be sampled in Fall 2009 and Spring 2010, along with any additional sites that are found to be suitable. We plan to conclude sampling in Spring of 2010, and to conclude all analysis and report activities by December 2010.

Acknowledgements

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Table 2-F. Site Information – Fall 2008

Stream	Station ID	Type	Order	Dominant Geology	County	Lat	Long
Burns Creek (reference)	BUR	Ref	2	Lee	Wise	36.929	-82.535
Clear Creek (reference)	CLE	Ref	2	Mississippian	Wise	36.929	-82.589
Eastland Creek (reference)	EAS	Ref	1	Mississippian	Wise	36.917	-82.593
Birchfield Creek	BIR	Test	2	Wise	Wise	37.036	-82.575
Grape Branch	GRA	Test	2	Norton	Buchanan	37.257	-82.007
Mill Branch Left Fork	MIL	Test	2	Wise	Wise	36.927	-82.747
Powell River	POW	Test	1	Wise	Wise	37.013	-82.697
Spruce Pine Creek	SPC	Test	2	Norton	Buchanan	37.261	-81.922

Table 2-S. Site Information – Spring 2009

Stream	Station ID	Type	Order	Dominant Geology	County	Lat	Long
Burns Creek (reference)	BUR	Ref	2	Lee	Wise	36.929	-82.535
Clear Creek (reference)	CLE	Ref	2	Mississippian	Wise	36.929	-82.589
Eastland Creek (reference)	EAS	Ref	1	Mississippian	Wise	36.917	-82.593
Birchfield Creek	BIR	Test	2	Wise	Wise	37.036	-82.575
Callahan Creek West Fork	CAW	Test	1	Wise	Wise	36.980	-82.797
Fawn Branch	FAW	Test	1	Wise	Lee	36.811	-83.080
Fryingpan Creek	FRY	Test	2	Norton	Dickenson	37.060	-82.218
Fryingpan Creek Right Fork	RFF	Test	2	Norton	Dickenson	37.060	-82.220
Gin Creek	GIN	Test	3	Wise	Lee	36.836	-83.055
Grape Branch	GRA	Test	2	Norton	Buchanan	37.257	-82.007
Hurricane Fork	HUR	Test	2	Norton	Buchanan	37.400	-82.067
Jess Fork	JES	Test	2	Wise	Buchanan	37.295	-82.219
Laurel Branch	LAB	Test	2	Norton	Russell	37.014	-82.205
Laurel Fork	LAU	Test	2	Wise	Wise	36.874	-82.825
Mill Branch Left Fork	MIL	Test	2	Wise	Wise	36.927	-82.747
Powell River	POW	Test	1	Wise	Wise	37.013	-82.697
Race Fork UT	RAC	Test	1	Norton	Buchanan	37.427	-82.050
Roll Pone Branch	ROL	Test	1	Norton	Russell	37.014	-82.195
Spring Branch	SPR	Test	1	Norton	Buchanan	37.434	-82.046
Spruce Pine Creek	SPC	Test	2	Norton	Buchanan	37.261	-81.922

Table 3-F. Field Physicochemical Parameters – Fall 2008

Stream	Temp (°C)	pH (SU)	D.O. (mg/L)	Cond. (μmhos/cm)
Burns Creek (reference)	1.74	7.26	10.96	24
Clear Creek (reference)	3.98	6.64	11.81	21
Eastland Creek (reference)	5.16	6.66	9.67	17
Birchfield Creek	7.04	7.61	11.56	755
Grape Branch	4.16	7.63	10.8	546
Mill Branch LF	2.53	7.68	12.25	1183
Powell River	2.75	7.54	10.89	865
Spruce Pine Creek	3.17	8.49	10.97	575

Table 3-S. Field Physicochemical Parameters – Spring 2009

Stream	Temp (°C)	pH (SU)	D.O. (mg/L)	Cond. (μmhos/cm)
Burns Creek (reference)	11.96	6.11	10.11	22
Clear Creek (reference)	11.47	7.8	9.93	16
Eastland Creek (reference)	11.67	6.85	10.21	21
Birchfield Creek	17.54	7.9	8.09	736
Callahan Creek West Fork	10.85	7.93	9.36	304
Fawn Branch	13.5	8.02	na	265
Fryingpan Creek	13.38	8.15	9.03	462
Fryingpan Creek Right Fork	13.02	8.45	10.22	607
Gin Creek	14.8	8.39	9.55	706
Grape Branch	13	7.56	9.16	143
Hurricane Fork	12.1	7.26	9.68	490
Jess Fork	12.14	6.57	10.17	757
Laurel Branch	14.16	7.9	8.27	842
Laurel Fork	15.03	6.9	8.59	25
Mill Branch Left Fork	14.06	8.25	8.69	878
Powell River	13.99	7.95	8.55	970
Race Fork UT	12.64	7.67	9.36	340
Roll Pone Branch	12.24	7.62	9.83	594
Spring Branch	13.21	7.51	7.81	339
Spruce Pine Creek	14.99	7.73	9.75	332

Table 4-F. Rapid Bioassessment Protocol Habitat Scores – Fall 2008

Stream	Substrate/Cover	Embeddedness	Velocity/Depth	Sediment Dep.	Flow	Channel Alt.	Riffle Freq.	Bank Stability L	Bank Stability R	Veg. Protection L	Veg. Protection R	Rip. Veg. Width L	Rip. Veg. Width R	Total
Burns Creek (ref)	19	16	15	15	14	20	19	8	8	9	9	10	10	**172**
Clear Creek (ref)	20	18	18	15	17	20	19	8	8	8	8	10	10	**179**
Eastland Creek (ref)	18	16	16	14	16	20	19	8	8	8	8	10	10	**171**
Birchfield Creek	17	17	15	13	15	20	19	8	9	9	9	7	9	**167**
Grape Branch	18	14	10	13	15	20	19	8	8	9	9	9	10	**162**
Mill Branch Left Fork	16	14	15	12	15	20	18	8	7	9	9	10	8	**161**
Powell River	17	15	15	12	16	20	19	7	7	8	8	10	10	**164**
Spruce Pine Creek	18	16	15	14	16	20	18	9	9	9	9	10	9	**172**

Table 4-S. RBP Habitat Scores – Spring 2009

Stream	Substrate/Cover	Embeddedness	Velocity/Depth	Sediment Dep.	Flow	Channel Alt.	Riffle Freq.	Bank Stability L	Bank Stability R	Veg. Protection L	Veg. Protection R	Rip. Veg. Width L	Rip. Veg. Width R	Total
Burns Creek (reference)	20	17	20	16	20	20	18	9	9	9	9	10	10	**187**
Clear Creek (reference)	20	16	18	13	19	20	20	9	9	10	10	9	10	**183**
Eastland Creek (reference)	20	17	15	15	19	20	20	9	9	10	10	10	10	**184**
Birchfield Creek	18	15	16	12	19	20	18	7	6	9	9	10	9	**168**
Callahan Creek West Fork	18	16	20	12	18	20	20	9	8	10	10	8	10	**179**
Fawn Branch	18	16	15	13	18	19	20	9	8	10	10	10	9	**175**
Fryingpan Creek	19	16	15	11	18	20	20	9	9	10	10	10	10	**177**
Fryingpan Creek Right Fork	17	16	15	14	19	20	16	9	9	9	9	9	10	**172**
Gin Creek	18	15	16	12	20	20	20	7	7	10	9	10	6	**170**
Grape Branch	18	16	16	13	18	20	20	8	8	9	9	9	10	**174**
Hurricane Fork	15	11	20	12	18	20	17	7	5	10	10	10	10	**165**
Jess Fork	16	14	15	13	18	20	17	7	7	8	8	9	6	**158**
Laurel Branch	18	14	15	12	20	20	19	8	8	9	9	9	9	**170**
Laurel Fork	17	17	15	12	15	20	16	7	7	10	10	10	10	**166**
Mill Branch Left Fork	15	12	15	12	17	20	16	8	9	9	10	10	9	**162**
Powell River	18	13	15	12	18	20	19	7	9	10	10	10	10	**171**
Race Fork UT	20	16	15	14	17	20	20	7	7	9	9	10	10	**174**
Roll Pone Branch	17	12	15	11	15	20	19	7	7	10	10	10	10	**163**
Spring Branch	18	15	15	13	17	20	19	8	8	10	10	10	10	**173**

Table 5-F. Total Dissolved Solids, Major Anions, and Alkalinity – Fall 2008

Stream	TDS (mg/L)	Anions (mg/L)		Alkalinity (mg/L)		
		Cl^-	SO_4^{2-}	Total	CO_3^{2-}	HCO_3^-
Burns Creek (ref)	5.2	2.3	5.4	9.9	0	9.9
Clear Creek (ref)	5.0	0.9	4.3	9.3	0	9.3
Eastland Creek (ref)	11.0	0.8	3.6	8.3	0	8.3
Birchfield Creek	555.6	8.4	233.3	153.2	7.2	146.0
Grape Branch	351.6	6.0	204.6	63.3	0	63.3
Mill Branch LF	861.8	2.0	213.1	165.6	11.8	153.7
Powell River	694.2	1.0	249.9	127.0	2.4	124.6
Spruce Pine Creek	364.4	3.8	128.4	207.1	10.5	196.6

Table 5-S. Total Dissolved Solids, Major Anions, and Alkalinity – Spring 2009

Stream	TDS (mg/L)	Anions (mg/L)		Alkalinity (mg/L)		
		Cl^-	SO_4^{2-}	Total	CO_3^{2-}	HCO_3^-
Burns Creek (ref)	37.4	2.7	4.6	0.6	0.0	0.6
Clear Creek (ref)	24.8	0.8	3.7	2.9	0.0	2.9
Eastland Creek (ref)	26.2	0.8	3.2	5.7	0.0	5.7
Birchfield Creek	538.4	3.2	378.2	107.2	0.0	107.2
Callahan Creek West Fork	205.4	0.9	100.1	65.9	0.0	65.9
Fawn Branch	168	1.1	68.0	73.7	0.0	73.7
Fryingpan Creek	298	9.8	156.0	70.7	0.0	70.7
Fryingpan Creek Right Fork	360.6	7.7	152.1	158.5	0.6	157.9
Gin Creek	470	8.5	155.0	251.6	4.3	247.3
Grape Branch	63.4	4.2	39.4	22.0	0.0	22.0
Hurricane Fork	290	1.4	220.9	32.1	0.0	32.1
Jess Fork	566.6	1.4	456.2	4.2	0.0	4.2
Laurel Branch	558.4	8.8	311.1	109.4	0.0	109.4
Laurel Fork	27.8	0.9	4.2	7.2	0.0	7.2
Mill Branch Left Fork	632.8	1.9	396.8	131.3	0.0	131.3
Powell River	791.6	1.0	531.4	115.6	0.0	115.6
Race Fork UT	217.8	1.2	114.4	79.9	0.0	79.9
Roll Pone Branch	389.2	4.5	249.6	78.6	0.0	78.6
Spring Branch	205.4	1.1	138.0	38.8	0.0	38.8
Spruce Pine Creek	173.6	5.7	109.3	45.6	0.0	45.6

Table 6-F. Major Cations and Trace Metals – Fall 2008

Stream	Major Cations (mg/L)				Trace Metals (μg/L)					
	K	Na	Ca	Mg	Al	Cu	Fe	Mn	Se	Zn
Burns Creek (ref)	0.5	4.1	1.1	0.5	< 2.8	< 8.9	< 39.4	< 1.7	6.4	< 37.3
Clear Creek (ref)	0.6	1.0	*2.6*	0.7	< 2.8	< 8.9	< 39.4	< 1.7	6.3	< 37.3
Eastland Creek (ref)	0.4	0.6	*2.5*	0.6	< 2.8	< 8.9	< 39.4	< 1.7	< 4.9	< 37.3
Birchfield Creek	4.9	27.9	75.3	55.0	< 2.8	< 8.9	52.4	< 1.7	< 4.9	< 37.3
Grape Branch	2.3	45.3	53.5	21.5	< 2.8	< 8.9	< 39.4	< 1.7	< 4.9	< 37.3
Mill Branch LF	5.4	36.4	158.7	66.9	< 2.8	< 8.9	410.9	160.3	7.5	< 37.3
Powell River	3.5	12.7	120.9	67.3	7.5	< 8.9	< 39.4	2.6	5.3	< 37.3
Spruce Pine Creek	1.8	84.9	40.2	17.3	< 2.8	< 8.9	< 39.4	< 1.7	< 4.9	< 37.3

Table 6-S. Major Cations and Trace Metals - Spring 2009

Stream	Major Cations (mg/L)				Trace Metals (ug/L)					
	K	Na	Ca	Mg	Al	Cu	Fe	Mn	Se	Zn
Burns Creek (ref)	0.4	1.9	1.3	0.6	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Clear Creek (ref)	0.3	0.4	1.7	0.6	41.9	<22.8	<22.2	<15.7	<24.1	<16.0
Eastland Creek (rer)	0.4	0.5	2.7	0.7	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Birchfield Creek	3.8	20.1	71.7	54.8	<9.8	<22.8	51.5	44.7	<24.1	<16.0
Callahan Creek West Fork	2.2	7.9	35.6	17.0	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Fawn Branch	2.3	10.4	28.5	14.3	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Fryingpan Creek	3.9	20.3	46.4	24.6	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Fryingpan Creek Right Fork	2.8	67.0	46.2	19.9	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Gin Creek	4.6	135.9	32.4	14.4	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Grape Branch	1.6	5.0	13.4	5.8	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Hurricane Fork	2.9	9.4	45.2	33.4	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Jess Fork	3.1	10.8	85.1	50.5	22.1	<22.8	74.8	787.9	<24.1	116.0
Laurel Branch	4.3	42.3	87.9	45.3	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Laurel Fork	1.4	1.0	2.2	1.5	<9.8	<22.8	319.9	<15.7	<24.1	<16.0
Mill Branch Left Fork	5.0	19.5	107.3	54.9	34.9	<22.8	100.2	37.9	<24.1	<16.0
Powell River	4.2	10.0	119.9	75.4	15.6	<22.8	72.0	<15.7	<24.1	<16.0
Race Fork UT	3.2	21.5	36.5	18.4	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Roll Pone Branch	2.9	18.5	65.3	33.4	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Spring Branch	2.2	3.3	36.0	24.0	<9.8	<22.8	<22.2	<15.7	<24.1	<16.0
Spruce Pine Creek	1.9	18.5	29.0	14.9	40.8	<22.8	24.3	61.5	<24.1	<16.0

Table 7-F. VA SCI Metrics and Final Score (200 organism sample) – Fall 2008

Stream	# Taxa	# EPT Taxa	% E	% PT-Hyd.	% Scrapers	% Chiron.	% 2 Dom.	HBI	VA SCI Score
Burns Creek (ref)	21	12	12.7	26.5	5.3	49.8	61.6	5.0	60.0
Clear Creek (ref)	22	15	28.1	30.8	14.6	22.2	43.2	3.9	76.3
Eastland Creek (ref)	23	14	3.5	42.4	13.5	14.7	37.1	3.5	75.5
Birchfield Creek	8	5	0.5	85.6	0.0	3.1	91.2	1.8	49.0
Grape Branch	17	11	3.3	55.7	2.7	1.6	75.4	3.1	65.2
Mill Branch LF	12	6	1.6	80.2	0.0	2.7	81.9	1.9	54.4
Powell River	12	8	0.6	71.0	1.2	3.6	82.8	2.4	56.5
Spruce Pine Creek	17	10	2.1	50.5	6.7	8.2	62.9	3.6	65.5

Table 7-S. VA SCI Metrics and Final Score (200 organism sample) – Spring 2009

Stream	# Taxa	# EPT Taxa	% E	% PT-Hyd.	% Scrapers	% Chiron.	% 2 Dom.	HBI	SCI Score
Burns Creek (ref)	18	13	7.0	69.3	8.5	14.6	57.8	2.4	69.5
Clear Creek (ref)	24	17	42.6	39.1	26.4	2.0	42.1	2.7	87.8
Eastland Creek (ref)	22	17	29.4	50.2	20.4	3.8	46.0	2.5	82.7
Birchfield Creek	12	6	0.0	60.4	0.5	16.2	61.9	2.9	56.1
Callahan Creek West Fork	14	11	15.6	77.6	6.3	4.2	68.2	1.7	67.9
Fawn Branch	16	13	22.6	70.9	12.1	3.5	61.8	1.7	73.1
Fryingpan Creek	15	11	31.7	52.3	11.1	1.5	42.7	2.5	77.8
Fryingpan Creek Right Fork	20	14	19.3	67.3	15.7	1.3	35.9	2.5	80.5
Gin Creek	19	12	38.7	43.3	10.8	9.3	43.8	2.8	80.3
Grape Branch	17	13	15.1	62.7	2.7	2.7	58.4	2.2	70.6
Hurricane Fork	20	12	19.7	63.6	5.8	2.9	54.3	2.3	74.7
Jess Fork	13	6	14.2	70.8	0.0	1.8	68.9	1.8	60.0
Laurel Branch	17	7	10.5	65.2	2.9	3.3	68.6	1.8	63.2
Laurel Fork	24	17	16.0	35.4	5.0	27.6	38.7	4.0	73.1
Mill Branch Left Fork	7	4	6.3	75.7	0.0	8.5	75.7	2.0	50.7
Powell River	15	8	31.0	37.9	20.2	2.0	50.7	3.2	75.0
Race Fork UT	15	12	17.9	77.7	6.1	1.7	68.7	1.5	69.1
Roll Pone Branch	12	10	16.3	81.3	2.4	1.4	70.2	1.2	64.8
Spring Branch	18	13	28.3	63.9	2.6	1.0	47.1	2.2	76.0
Spruce Pine Creek	15	8	15.8	52.5	6.0	12.6	56.3	2.7	66.1

Figure 2. Clear Creek (reference), Wise County, Virginia.

Figure 3. Grape Branch (test), Buchanan County, Virginia.


Figure 4. Roll Pone Branch (test), Dickenson County, Virginia.

Appendix

Table A-8. Fall 2008 VSCI metrics and scores, 110 (±10%) organism subsample

Stream	# Taxa	# EPT Taxa	% E	% PT-Hyd.	% Scrapers	% Chiron.	% 2 Dom.	HBI	SCI Score (110 org)
Burns Creek (ref)	18	11	13.8	31.2	5.5	44.0	57.8	4.6	62.3
Clear Creek (ref)	18	12	30.5	26.3	17.9	20.0	42.1	3.9	74.3
Eastland Creek (ref)	22	13	5.2	39.2	16.5	11.3	37.1	3.5	76.9
Birchfield Creek	5	3	0.0	87.4	0.0	1.9	96.1	1.6	44.2
Grape Branch	14	9	4.0	54.8	3.2	2.4	73.0	3.2	61.8
Mill Branch LF	10	6	1.9	78.3	0.0	3.8	82.1	2.0	53.2
Powell River	9	6	0.0	69.1	2.1	3.1	83.5	2.6	52.5
Spruce Pine Creek	14	7	0.0	53.4	6.0	8.6	65.5	3.5	59.5

Table A-9. Spring 2009 VSCI metrics and scores, 110 (±10%) organism subsample

Stream	# Taxa	# EPT Taxa	% E	% PT-Hyd.	% Scrapers	% Chiron.	% 2 Dom.	HBI	SCI Score (110 org)
Burns Creek (ref)	14	10	8.0	64.6	7.1	18.6	58.4	2.6	65.3
Clear Creek (ref)	18	13	41.3	40.4	25.7	0.0	44.0	2.6	85.0
Eastland Creek (ref)	19	14	27.7	53.8	16.0	3.4	46.2	2.3	79.6
Birchfield Creek	10	6	0.0	58.0	0.0	18.8	61.6	3.1	54.6
Callahan Creek West Fork	14	11	15.7	78.7	6.5	3.7	63.9	1.7	68.8
Fawn Branch	16	13	18.8	74.1	9.8	2.7	61.6	1.7	71.9
Fryingpan Creek	14	11	28.9	53.5	14.0	0.9	38.6	2.5	78.2
Fryingpan Creek Right Fork	15	11	18.3	69.2	18.3	0.8	40.8	2.5	77.3
Gin Creek	19	12	39.3	42.6	13.1	8.2	41.0	2.8	81.6
Grape Branch	14	10	10.1	59.6	2.0	3.0	59.6	2.5	66.3
Hurricane Fork	15	10	22.4	62.1	6.0	4.3	53.4	2.3	71.3
Jess Fork	10	5	15.7	69.3	0.0	0.8	68.5	1.8	57.7
Laurel Branch	16	7	10.2	63.9	1.9	5.6	63.9	2.0	62.9
Laurel Fork	19	13	17.5	34.2	4.4	25.4	37.7	4.0	71.6
Mill Branch Left Fork	7	4	4.6	72.5	0.0	10.1	72.5	2.1	50.7
Powell River	13	7	30.0	35.8	20.8	3.3	49.2	3.3	72.5
Race Fork UT	14	11	21.2	72.1	6.7	1.9	65.4	1.6	69.9
Roll Pone Branch	10	8	17.4	78.9	0.0	2.8	71.6	1.3	60.6
Spring Branch	18	13	26.0	62.0	2.0	1.0	44.0	2.4	76.0
Spruce Pine Creek	11	6	17.0	52.8	7.5	13.2	58.5	2.5	61.7

A preliminary assessment of ecosystem function in Virginia coalfield streams

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Introduction

The United States possesses one-fourth of the world's coal resources, with more than 260 billion tons of recoverable reserves (USDOE 2009). Given political instability in world regions from which the US imports energy supplies, national security concerns demand continued use of domestic energy supplies. The Appalachian coalfields, including southwest Virginia, are a primary coal-producing region in the US, and are projected by the US Department of Energy to remain as such over the coming decades (USDOE 2009). Coal production to date has disturbed >0.6 million hectares and impacted > 2000 km of headwater and low order streams in Appalachia (USEPA 2005).

Prior to the European settlement of southwestern Virginia, the headwater streams of this region were closely connected to the forests of their watersheds and provided important ecosystem services. These forests provided shade, which limited in-stream photosynthesis and moderated stream temperature. These forests provided inputs of leaves, the primary nutritional source for aquatic invertebrates and, indirectly, fish. The forests and streams acted as filters, preventing sediments and nutrients from being transported downstream. Streams and rivers in this region of central Appalachia have also been recognized as a globally significant biodiversity resource, having some of the most significant concentrations of rare, threatened, and endangered aquatic species in North America. Even before coal mining, the forests had been cleared or selectively logged. Important tree species such as chestnut had been lost to disease. Farming and woodland grazing had greatly modified the function of forests and streams. Many of the streams and their watersheds have now been further degraded or lost completely as a result of surface coal mining.

Restoration of coal-mine sites is required by federal law. In response to increasing public concern and the expanding scale of coal-mining operations, there is an increase in the legal requirements for environmental restoration by mining operations. Coal mine operators are now being asked to restore the physical and biological structure of streams, and to consider the restoration of stream function. A major difficulty with this task is that there is little information in existence to guide and evaluate such efforts.

Our research is intended to assess the effectiveness of stream restoration activities in an area of central Appalachia that is faced with the challenge of managing current energy extraction that is vital to the economic sustenance of local communities. Sustainable development of these areas demands that the structural and functional characteristics of water resources damaged or lost to surface mining operations be re-established. It is unlikely that pre-settlement state of stream function can ever be achieved by watershed and stream restoration, but with the paucity of data, a survey of current practices is vital. Our primary objective in this study is to identify headwater streams that have undergone restoration efforts following coal mining in the southwestern Virginia coalfields and conduct field and laboratory studies aimed at measuring selected structural and functional attributes. In terms of structure, we evaluated habitat quality, along with biotic assemblages present in these streams. Important ecosystem functions, including nutrient uptake and ecosystem metabolism, were also assessed.

Methods

Site Selection- Site selection occurred during Autumn 2008 and Winter 2008-2009 in the coal mining region of southwest Virginia, including the counties of Dickenson, Russell, Wise, and Buchanan. Because of a drought during the summer of 2008, many streams in this region of Virginia had no surface water flow, which impeded our ability to find an adequate number of streams initially. After sufficient rainfall had occurred during the winter of 2008, six restored and three unrestored sites were chosen for this study (Table 1), all of which had been historically disturbed by coal mining activities or logging. Restored sites generally refer to those streams that have undergone Natural Stream Channel Design methods, with the exception of Critical Fork. In contrast, Critical Fork, the oldest restored stream, was reconstructed by the coal mining operation as a purposeful effort to restore natural stream channel conditions. Although the in-stream restoration of these streams was mostly consistent, the landscape from which they were created varied (Photos 1 – 3). Critical Fork is a reconstructed channel that currently drains a sediment retention pond. Portions of Chaney Creek, Stonecoal Creek, and Laurel Branch were created from drained sediment retention ponds, whereas Left Fork was created as a new channel (Lance DeBord, personal communication). Lick Branch is the only site that is fed by active deep-mine effluent discharge. Additionally, the riparian zones were rebuilt and planted with vegetation in a manner that varied from site to site, leading to unique drainage and infiltration patterns across the 6 restored streams (personal observation). Unrestored sites have undergone no in-stream or riparian restoration, but do have disturbance including past coal mining in their catchments. Two of the three unrestored sites (N. Laurel and N. Chaney) were upstream segments of streams with restored study sites.

Within each stream, a 100-meter reach was delineated for habitat, biological, and functional measurements outlined below.

Habitat Assessment- Assessment of each stream took place during June 2009, and followed protocol outlined in Barbour et al. (1999) and VDEQ (2008). In brief, for each 100-meter reach of stream sampled (along with an additional 100-m section upstream from the top of the experimental reach), in-stream habitat and riparian structure were assessed using a variety of physical metrics. In-stream, visual evaluations of substrate cover, embeddedness, velocity regime, sediment deposition, channel flow status, channel alteration, and riffle/bend frequency were completed, with each being assigned a score ranging from 0-20 points. Riparian features for each bank, including bank stability, vegetative protection, and riparian zone width were also assessed and scored similarly to above. Maximum scores of 200 points could be obtained, with stream condition being classified as Poor, Marginal, Suboptimal, or Optimal, which represent <25%, 25-50%, 50-75%, or 75-100% of the total score possible based on metrics noted above.

Abiotic Parameters- Abiotic parameter measurements were taken throughout the sampling period. An estimate of discharge in each stream was determined using a NaCl slug (Webster and

Valett 2006). Dissolved oxygen and pH were measured using a portable sonde (Hydrolab Quanta, Hach Instruments, Loveland, CO), while specific conductance and temperature were taken with a conductivity meter (YSI, Inc., Yellow Springs, OH). Grab samples were collected for analysis of total dissolved solids (TDS) following Standard Methods (APHA 1998). Samples were transported and stored at 4°C prior to filtration and drying at 180°C in the laboratory. Methods for obtaining ammonium (NH_4^+), nitrate (NO_3^-), and phosphate (PO_4^{-3}) are outlined below.

Macroinvertebrate Collections- Stream surveys for aquatic macroinvertebrates in all streams took place during 9-10 June 2009. As per methods outlined in Barbour et al. (1999) and VDEQ (2008), six ~0.3m^2 kicks (2m^2 composite total) were taken with a 500 micron d-frame net for 30 seconds at each site. All material collected during sampling were placed in containers of 95% ethanol for transport back to the lab for identification. Laboratory processing of biological samples followed Virginia DEQ protocols (VDEQ 2008). Organisms were separated from debris using a randomized subsorting procedure to obtain 110 (+/- 10%) organisms for identification. Standard taxonomic keys (Merritt et al. 2008) were used to identify organisms to the family/lowest practicable level. Benthic macroinvertebrate metrics were calculated and Virginia Stream Condition Index (VSCI) scores obtained following formulae detailed by Burton and Gerritsen (2003). Aquatic life impairment status was determined based on each site's VSCI score. Sites scoring < 60 are considered impaired and sites with scores ≥ 60 are unimpaired. (VDEQ 2007).

Nutrient Uptake- The ability of stream biota to process nutrients for growth and maintenance is an important function of stream ecosystems. Movement of nutrients downstream between organic and inorganic compartments is termed "nutrient spiraling" (Webster and Patten 1979, Newbold 1992), with more efficient streams assimilating nutrients at a much faster rate as a result of biotic demand (i.e. tighter nutrient spirals; Allan and Castillo 2007). More efficient streams are able to better process nutrient loads, as opposed to simply acting as a "pipe" sending excess nutrients farther downstream into rivers and estuaries. As such, we measured ammonium uptake lengths (Webster and Valett 2006) during the dormant (Autumn/Winter 2008-2009) and growing seasons (Summer 2009) at each of the 9 sites. A co-injection of ammonium (as NH_4Cl) and a conservative tracer (NaCl) were added to the streams at a constant rate using a metering pump. A conductivity meter was used to monitor the conservative tracer. After the conservative tracer had reached equilibrium, samples were taken at seven transects within a study reach of approximately 100 m length, depending on flow at the time of the study. Triplicates of stream water were collected and filtered through a 0.7µm glass fiber filter at each of the seven sites along the reach. Samples were analyzed for chloride and nitrate, using ion chromatography (DX 500 IC, Dionex Corp., Sunnyvale, CA), and ammonium and phosphate, using flow injection analysis (Lachat QuickChem 8500, Lachat Instruments, Loveland, CO). Uptake length (S_w) was calculated as the negative inverse of the regression slope of flow-corrected ammonium concentration versus distance. We also calculated uptake velocity (v_f) and areal uptake (U) (Webster and Valett 2006).

Ecosystem Metabolism- Another major function of stream ecosystems is their ability to process organic matter (Allan and Castillo 2007). We measured stream metabolism (gross primary production and ecosystem respiration) at each of the 9 sites using standard whole-stream/open channel methods with conservative gas (SF_6) injections for estimating site-specific reaeration coefficients (Bott 2006). Dissolved oxygen, water temperature, and conductivity were measured at 2-min intervals over a 36-h period at each site using Hydrolab mini-sondes (Hach Environmental, Loveland, CO). Metabolism was calculated using the single station method (Bott 2006, Grace and Imberger 2006).

Results

General Stream and Macroinvertebrate Measurements- Restored sites used in this study ranged in age from 1- 10 years, with most sites completed within the past four. Based on EPA (Barbour et al. 1999) and VDEQ (2006) ratings, half of the restored sites were optimal in terms of habitat, whereas the other three were suboptimal (Table 1); all unrestored sites were classified as optimal (Table 1). Difference in mean habitat scores between restored and unrestored sites were not significant (t-test, $p > 0.1$)

Abiotic stream measurements were more variable across sites, although all pH values were circumneutral. Summertime discharges of streams were generally greater than in the autumn/winter, except for Stonecoal, North Chaney, and North Laurel Branch, where the opposite was true (Figure 1). Stream temperatures were consistently higher in the summer as well (Figure 2). Specific conductance varied across sites and seasons, but lower values were recorded in the summer for six of the nine sites (Figure 2). Stonecoal had the lowest measured specific conductance (159.3 ± 0.6, 265.6 ± 0.8 uS cm^{-1} in autumn/winter and summer, respectively), whereas Critical Fork had the highest (1,617.9 ± 1.2, 1,220.1 ± 3.2 uS cm^{-1} in autumn/winter and summer, respectively). Total dissolved solids also showed high variation (Table 2), with restored Critical Fork having the highest concentration (1,223.6 mg L^{-1}); overall, restored and unrestored sites did not demonstrate significantly different mean TDS concentrations (t-test, $p > 0.1$). In terms of background nutrient levels, ammonium was below analytical detection limits except in both reaches of Chaney Creek, whereas nitrate was detectable in each stream (Table 2). Phosphate was below analytical detection limits in all streams (<2 µg L^{-1}).

Virginia Stream Condition Index (VSCI) analyses provided fairly consistent results across all nine streams (Table 3), with restored and unrestored sites not significantly different (t-test, $P > 0.05$). All restored sites demonstrated a level of stress in terms of the macroinvertebrate assemblages found, except for Lick Branch, where severe stress was noted. Among the unrestored sites, only the macroinvertebrate assemblage in North Chaney Creek indicated stress, whereas the other unrestored sites scored "good" conditions (SCI>60). Habitat scores in all sites were significant predictors of VSCI (linear regression, $r^2 = 0.60$, $p = 0.01$), whereas total dissolved solids was not as strong ($r^2 = 0.37$, $p = 0.08$; Figure 3). Similar regressions on data from only restored sites demonstrated relationships between VSCI vs. habitat scores ($r^2 = 0.47$, $P = 0.13$) and VSCI vs. TDS ($r^2 = 0.58$, $P = 0.08$), but these relationships were not significant at $p<.05$ (Figure 3).

Ammonium Uptake- Streams showed seasonal variation in discharge and uptake parameters, while no distinct patterns were noted for restored and unrestored sites within the same season. Ammonium uptake lengths were variable across sites and seasons. Uptake velocities also demonstrated a high degree of variability (0.1-4.4 mm s^{-1} in autumn/winter and 0.2-3.5 mm s^{-1} in the summer), with higher velocities occurring during the summer in all but 1 restored site and the unrestored Powell River site. Uptake rate was also variable but showed a similar pattern as described for uptake velocity. Lick Branch consistently had the greatest uptake velocity and rate among sites during both seasons.

Ecosystem Metabolism- Both gross primary productivity (GPP) and ecosystem respiration were variable across sites over the study period. Respiration estimates were consistently greater than those for GPP, leading to productivity/respiration (P/R) ratios consistently < 0.5, except for Stonecoal Creek, during the summer of 2009.

Discussion and Conclusions

Inconsistencies in restoration methods and the overall impacted nature of all nine sites likely produced the wide variation in much of the data that we collected. Most of the streams that we used for this study contained macroinvertebrates indicative of impaired environments (noted by both the VSCI scores and the low numbers of EPT taxa, Table 3), regardless of habitat suitability. Habitat is a factor that may be manipulated through mine reclamation and reconstruction/restoration processes, and, as it is a significant predictor of VSCI, should be at the forefront of future projects on impacted streams in this region. Woody canopy was a major differentiating feature among stream-type habitats, as all non-restored streams were under mature woody canopy. Although woody canopy was developing within the riparian zones of most restored streams, that development was many years shy of the mature woody canopy that characterized the non-restored sites.

As postulated by the River Continuum Concept (Vannote et al. 1980), small headwater streams should have a net heterotrophic status because of a predominance of canopy cover and reliance on allochthonous materials to drive energy flow within the system. The nine streams assessed in this study appear to be net heterotrophic across seasons. Although rates of GPP were higher in some streams during the growing season, increased respiratory demand diminished the impact of this production. Only Stonecoal showed a P/R >1 during the growing season. In this stream, discharge was extremely low leading to a large portion of the benthic area being exposed to air. A possible reason for this result is the presence of multiple deep pools (0.5-1m) that may act as a hotspot of primary production (Freeman et al. 1994, Lake 2003).

Nutrient limitation may have also hindered primary production in these streams during the summer, even though streams appeared to have ample amounts of nitrogen and all restored streams had an open canopy. We measured phosphate in our stream samples on all occasions, and consistently found values below the detection limits of our analyses, suggesting a possible P-limitation.

Our major objective in this study was to gather information on the structural and functional attributes of restored streams in the coal mine regions of southwest Virginia to enhance our understanding of these systems. We were able to collect valuable baseline data in this survey that will contribute to the knowledge of restoration practices and their effects on stream function in this region. Even so, we were not able to truly discriminate between restored and unrestored streams, as all functional measures varied independently of stream type. Restoration practices could be classified as a form of disturbance, such that studies in other regions have noted a lack of return to satisfactory ecological condition even a decade or more post restoration (Charbonneau and Resh 1992, Kondolf 1995). The variation in our data also point out the innate diversity of streams, regardless of how similar restoration practices attempt to make them. Given time, these restored streams may return to a more ecologically functional condition, but our data demonstrate that more work should be done to better understand restoration and the effects on all aspects of stream ecosystems.

Acknowledgements

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Photo 1. The restored stream channel at Chaney Creek, in June 2009.

Photo 2. Critical Fork in June, 2009.

Table 1. Site descriptions of study streams in southwestern Virginia.

Site	Location	Site Type (age)	Habitat Score[1]	Condition
Chaney Creek	Russell County	Restored (3 y)	160	Optimal
Critical Fork	Wise County	Restored (>10 y)	145	Suboptimal
Laurel Branch	Russell County	Restored (4 y)	171	Optimal
Left Fork	Dickenson County	Restored (2 y)	133	Suboptimal
Lick Branch	Wise County	Restored (3 y)	136	Suboptimal
Stonecoal Creek	Russell County	Restored (1 y)	162	Optimal
North Chaney Creek	Russell County	Unrestored	154	Optimal
N. Laurel Branch	Russell County	Unrestored	170	Optimal
Powell River	Wise County	Unrestored	170	Optimal

[1] Habitat assessment scores were based on habitat metrics outlined in Barbour et al. (1999) and adapted for VDEQ (2008), stream condition may be classified as Poor, Marginal, Suboptimal, or Optimal, representing habitat score of <25%, 25-50%, 50-75%, or 75-100% of the total score possible.

Table 2. Abiotic parameters for restored (R) and unrestored (U) study streams in southwestern Virginia.[1]

Site	Site Type	DO ($mg L^{-1}$)	pH	TDS ($mg L^{-1}$)	NH_4^+ ($\mu g L^{-1}$)	NO_3^- ($mg L^{-1}$)
Chaney Creek	R	7.6	7.9	319.6	8.1	0.2
Critical Fork	R	9.3	8.1	1223.6	BD	3.0
Laurel Branch	R	8.4	7.7	551.6	BD	0.7
Left Fork	R	8.1	7.6	922.0	BD	0.8
Lick Branch	R	8.8	8.4	906.8	BD	1.1
Stonecoal Creek	R	7.5	7.9	119.2	BD	0.2
N. Chaney Creek	U	7.2	7.7	324.2	12.1	0.1
N. Laurel Branch	U	8.3	7.9	558.4	BD	0.7
Powell River	U	9.2	7.9	706.8	BD	1.3

[1]Dissolved oxygen (DO), pH, and total dissolved solids (TDS) were measured from 9-10 June 2009. Ammonium and nitrate were measured during 2009 summer sampling period. Minimum detection limit for ammonium=5 $\mu g L^{-1}$. BD=below detection limit. Phosphate was below analytical detection limits (2 $\mu g L^{-1}$) in all streams.

Photo 3. Laurel Branch in 2008.

Table 3. Biotic indices for study streams in southwestern Virginia. [1]

Site	Abund.	# taxa	# EPT	VSCI	ALU tier
Chaney Creek	98	12	5	58.2	Stress
Critical Fork	110	7	3	45.4	Stress
Laurel Branch	116	10	7	56.7	Stress
Left Fork	130	9	4	54.0	Stress
Lick Branch	102	3	1	38.8	Severe Stress
Stonecoal Creek	107	13	6	59.2	Stress
N. Chaney Creek	116	14	7	58.8	Stress
N. Laurel Branch	108	16	7	62.9	Good
Powell River	108	10	6	66.2	Good

[1]Included in this table are the total abundance (Abund.), total numbers of taxa (# taxa), Ephemeroptera-Plecoptera-Tricoptera taxa (EPT), Virginia Stream Condition Index Scores (VSCI), and aquatic life use (ALU) tiers (VDEQ 2006, 2008).

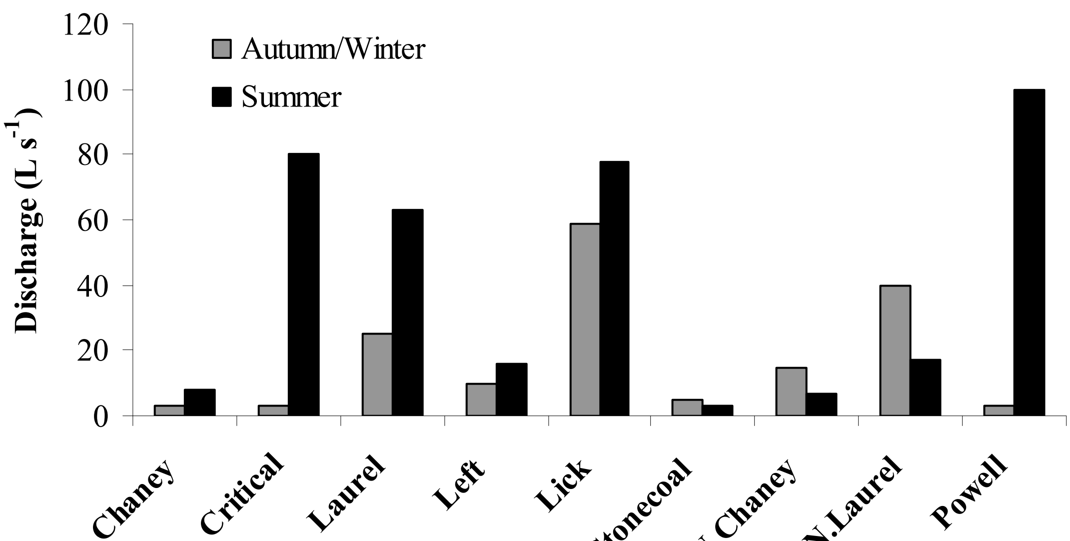

Figure 1 Seasonal discharge for the nine study streams in southwestern Virginia. Restored sites are to the left (Chaney to Stonecoal). The three unrestored sites are to the right (North Chaney to Powell River).

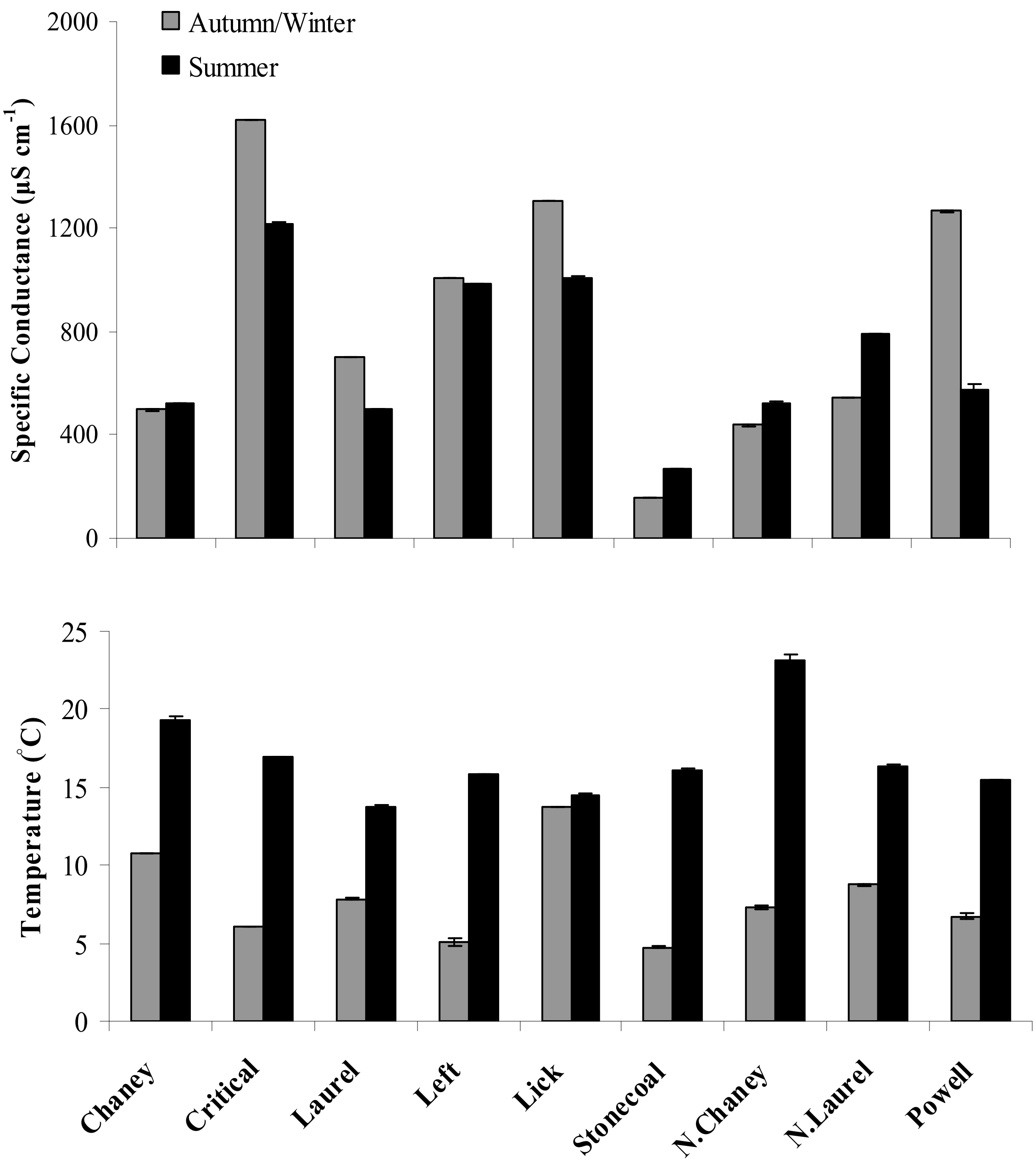

Figure 2. Specific conductance and temperature for the nine study streams in southwestern Virginia. Error bars represent ± 1 SD. Restored sites are to the left (Chaney to Stonecoal). the three unrestored sites are to the right (North Chaney to Powell River).

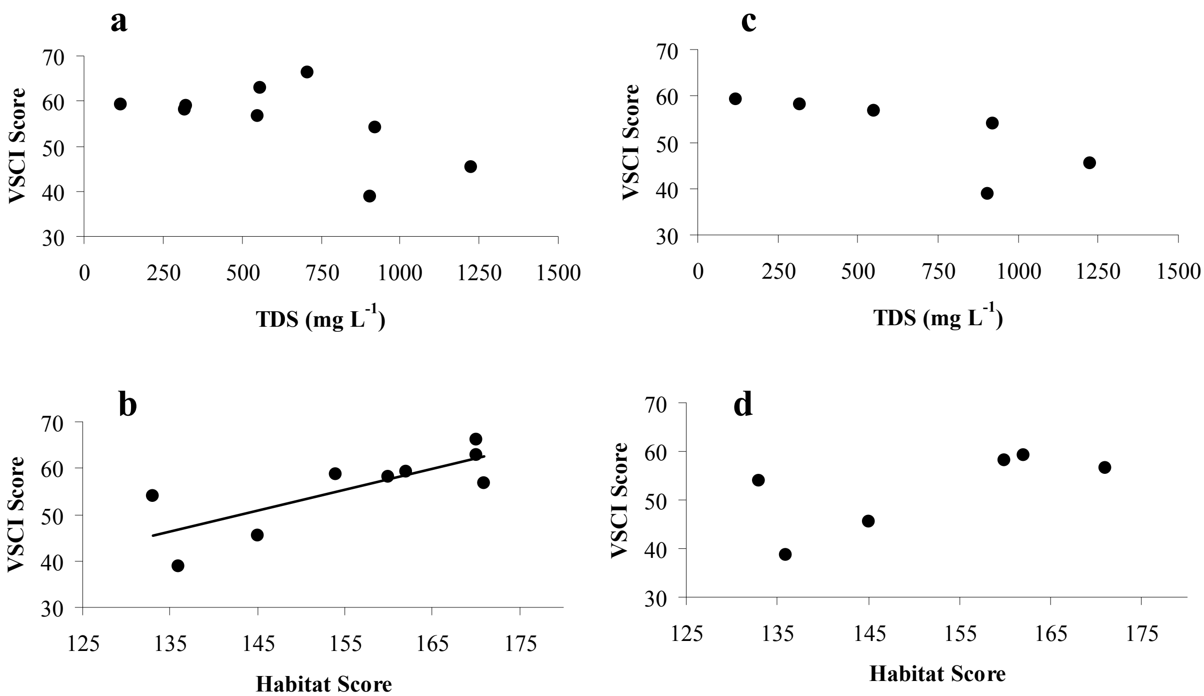

Figure 3. Linear regressions between a) TDS vs. VSCI in all sites, b) Habitat Score vs. VSCI in all sites, c) TDS vs. VSCI in the 6 restored sites, and d) Habitat Scores vs. VSCI in the 6 restored sites. Plots showing regression lines were significant at α = 0.05.

MONITORING THE HEALTH AND PRODUCTIVITY OF POWELL RIVER PROJECT FORESTS WITH SPECIAL EMPHASIS ON SUSTAINING HIGH-VALUE AND BIOLOGICALLY DIVERSE RECLAMATION SYSTEMS

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Introduction

Southwestern Virginia is well-known for coal. Yet forest resources management is also a critical part of the region's character and economy. For more than 25 years, the Powell River Project has played a key role in hosting research and education to support mining industry efforts to develop effective methods for reclaiming mined lands with forests. Now, partners are working to take the next step in reclamation on coalfields by researching and demonstrating profitable and sustainable forest management practices in the Powell River Project's natural and planted forests (see "A Working Laboratory at the Powell River Project To Research and Promote Sustainable Forest Management" by Munsell, Rockett, Worrell, and Whiteley in the Powell River Project's 2008 report). Rehabilitating degraded natural forests adjacent to reclaimed stands will provide examples of the benefits associated with forest restoration, while efforts to record the changing state and function of forests planted after mining operations will help scientists develop systematic approaches for profitably and sustainably managing reclamation forests. Sustainable forest management education offered through the Powell River Project Research and Education Center via Virginia's Link to Education about Forests (LEAF) partnership will offer programs related to managing productive, healthy, and diverse forested ecosystems on mining lands. This report documents the initiative's progress during the past year.

Background

Virginia Cooperative Extension and Virginia Tech's Department of Forest Resources and Environmental Conservation continue their efforts to take the next step in coalfield reclamation by researching and demonstrating sustainable forest management in natural and planted forests at the Powell River Project. The purpose is twofold: 1) monitor the health and productivity of reclamation forests with special emphasis on the long-term management of sustainable, high-value systems and 2) develop and administer a corresponding educational program via Virginia's LEAF partnership that regularly conveys critical insights and recommendations to stakeholders for profitably and sustainably managing forested ecosystems on Appalachian mining lands. Objectives consist of tracking species composition, health, and productivity in reclamation stands over time, developing systematic and operationally feasible silvicultural prescriptions to achieve a variety of goods and services over the course of stand rotation, and rehabilitating degraded adjacent natural forests using controlled, low-intensity burning and thinning. During the summer of 2009, a field technician re-measured a portion of overstory, regeneration, herbaceous, and downed woody debris plots established in 2008 in 4 Compartments (A, B, C, D) on about 200 acres of adjacent degraded natural forests (Figure 1). The technician also established a similar inventory system on a 15-acre mixed-species reclamation stand of about 7 years in age.

Methods

In April 2008, a 12-acre controlled, low-intensity burn was conducted in concert with Virginia's Department of Forestry in Compartment A (Figure 2). The purpose was to reduce invasive species, enhance desirable regeneration, and prepare for future restorative cutting in a stand directly adjacent to the Education Center complex. In the summer of 2008, comprehensive forest inventory research plots were established in the treated compartment to track impacts on invasive vigor and compare herbaceous cover and tree regeneration with like data from similar plots in an adjacent control compartment (Compartment B).

The tenth-acre over-story plots, mil-acre regeneration plots, and woody debris transects were re-inventoried in Compartments A and B during the summer of 2009. Stems one inch in diameter at breast height (dbh) and greater were inventoried. Future inventories are planned to track the long-term impact of the burn treatment and inform follow-on restorative cutting. Plots in Compartments C and D were also spot-checked for consistency with 2008 measurements. Like forest inventory plots using 1/24th acre circular boundaries were established in a 7 year old, 15-acre mixed-species reclamation stand – Compartment E (Figures 1 and 3). Dbh, basal area, live crown ratio and crown positions were recorded. Merchantability was determined for each tree and a grade of acceptable or unacceptable growing stock was given based on species, bole shape, crown position and tree damage. The entire inventory system was mapped using a Global Positioning System. Data collected at each plot will be used to monitor the health, productivity, and diversity of the stand and identify management prescriptions and operational guidelines to achieve profitable and sustainable reclamation stand management.

The authors wish to express their gratitude for support from the Powell River Project, Virginia's SFI Implementation Committee, and Virginia's LEAF Partnership.

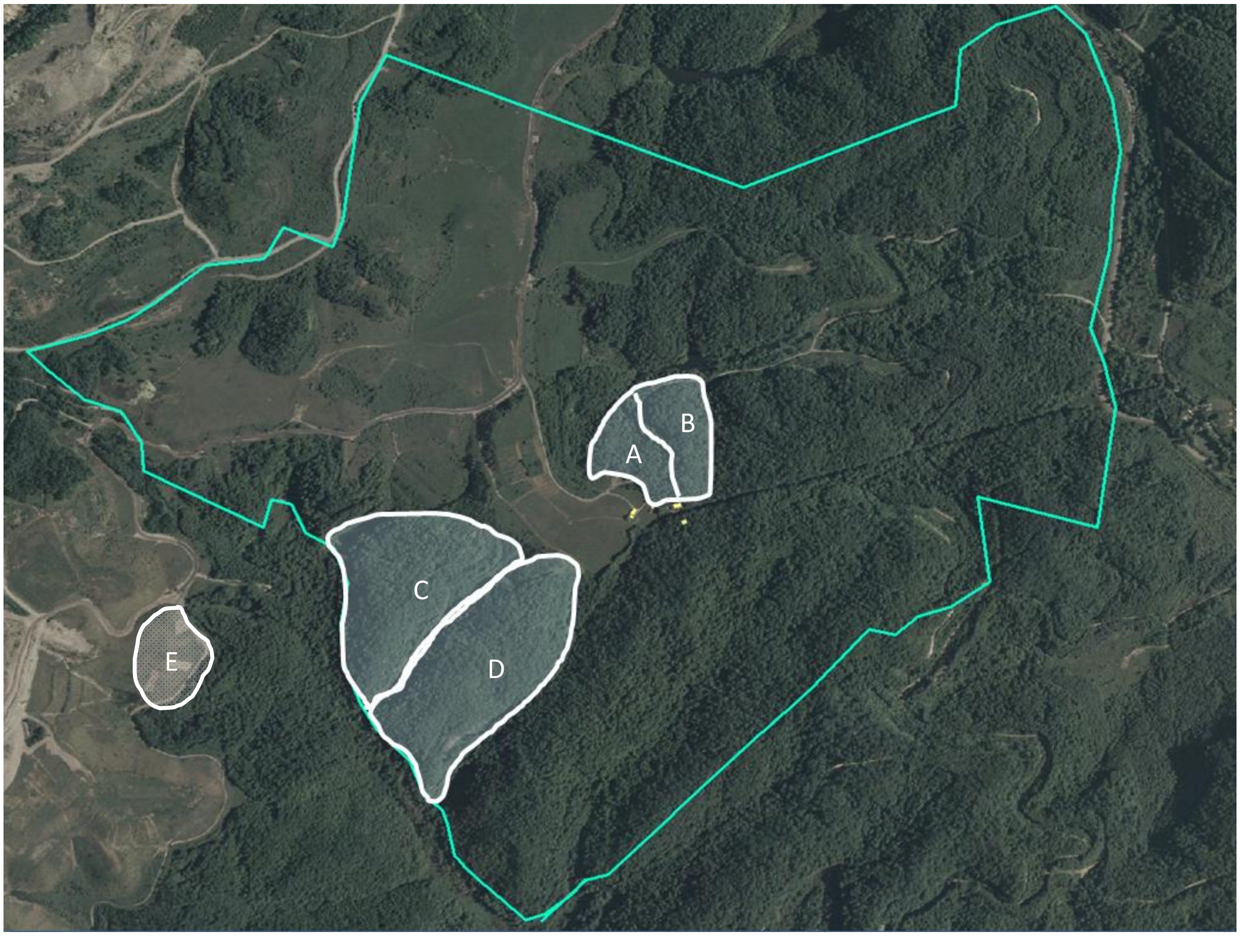

Figure 1. Four natural forest compartments (A, B, C, D) at the Powell River Project inventoried during the summer of 2008. Compartments A and B were fully re-inventoried and C and D spot-checked during the summer of 2009 and a comprehensive permanent forest inventory system established in Compartment E.

Figure 2. Virginia’s Department of Forestry conducting a controlled burn in Compartment A.

Figure 3. Comprehensive forest inventory plot system established in Compartment E during the summer of 2009. Baseline data were collected via the system. Future inventory will provide time series changes in the maturing, mixed-species reclamation stand. Results will assist in designing best practices to sustain health, diversity, and productivity.

Beef Cattle Reproduction on Reclaimed Strip-mined Land

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Reproductive efficiency markedly affects the economics of beef cattle production units. The National Cattleman's Association-Integrated Resource Management- Standard Performance Analysis (SPA) evaluation has analyzed economic and performance data from beef herds across the United States. When herds that are in the first quartile for profitability are compared with those in the bottom quartile a weaning percentage of 85.2% is achieved over the 81.5% of the lowest quartile. This figure couples with the 42 extra pounds of weaning weight achieved by the high profitability producer to allow them to achieve a 14.2% return on assets at cost compared with a -4.75% for the lowest profitability group. When CATTLE-FAX prepared information indicating the economic impact of a 10% factors change in key affecting break-even prices on a dollars/CWT basis they documented that largest change in break-even prices occurs by increasing the weaned calf crop by 10%. This is closely followed by increasing weaning weights of calves by 10%. Other factors considered resulted in changes in break-even prices of only one-half to one-fifth as much.

Table 1 is a summary of losses occurring at the various stages of the beef reproduction cycle as reported in four independent studies. Note that in each case the largest losses occurred because cows failed to become pregnant during the breeding season. In these studies, 7-22% of cows exposed to bulls were not pregnant at the end of the breeding season. These figures are lower than the SPA data that probably comes from more motivated producers who are willing to keep and share extra records Note, further, from Table 1 that for each 100 cows exposed to a bull only 62.5-77 calves are eventually weaned. These figures indicate the magnitude of loss that is resulting from reproductive inefficiency and pinpoint the phases of the reproduction cycle where major losses occur. (Note also that traditional herd-health programs based mainly on vaccination programs designed to decrease gestational and growing calf loss aim at the two areas where fewest losses occur.)

For an individual cow to achieve maximum reproductive efficiency a calf must be produced every 12 months on the average. Remembering that gestation length in the bovine is approximately 285 days, only 80 days (on the average) may elapse between parturition and conception. The two major factors that will influence the cow's ability to achieve this are: 1) the amount of time which elapses between calving and the resumption of the estrus cycle and, 2) the percentage of matings which result in pregnancy--the conception rate. Major factors influencing cycling after calving and the conception rate will be considered in this paper in some detail.

Table 1. Calf losses related to stage of reproduction cycle.

Location & Length of Study	# of Cows in Breeding Herd Season (%)	Not Pregnant at End of Breeding (%)	Calves Lost During Gestation	Lost Near Birth (%)	Lost Birth to 2 Weeks (%)	Lost 2 Weeks to Weaning (%)	Calf Crop Weaned (%)
Miles City Montana (14 yr)	12,827	17.4	2.3	6.4	2.9	---	71. 0
Front Royal Virginia (2 yr)	822	12.0	3.5	6.0	3.0	1.5	71.5
Iberia Louisiana (2 yr)	462	22.0	4.0	3.5	4.5	0.5	62.5
Fort Robinson Nebraska (1 yr)	530	7.0	3.0	6.0	6.0	1.0	77.0

From: Wiltbank, J.N. (1983).

Factors Affecting After-Calving Cycling

If high pregnancy rates are to be achieved, a large percentage of cows must resume the estrus cycle early in the breeding season. This becomes apparent when considered in light of conception rates. If a 63-day breeding season is used and 70% conception is achieved, a 98% pregnancy rate could theoretically occur if all cows were cycling at the onset of the season. If the average cow does not begin cycling until 45 days into the season a pregnancy rate of only 81% would result. The following six factors which are believed to be the most important in promoting the initiation of estrous activity will be discussed.

-Time of calving
-Age of the cow
-Body condition of cows at calving
-Suckling
-Presence of a bull
-The use of exogenous hormones

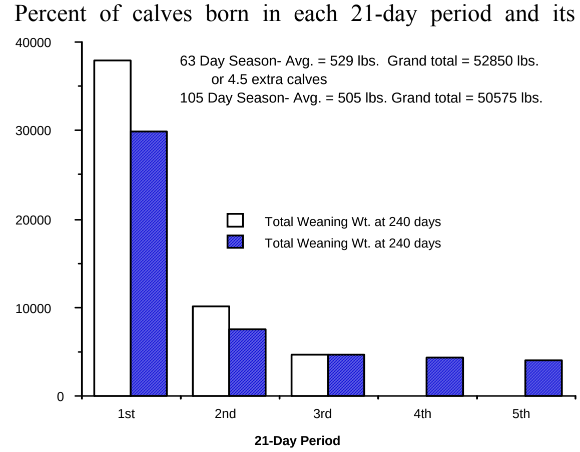
Time of calving

The time during the previous calving season that a cow calves greatly influences the time that the cow may manifest estrus in the succeeding breeding season. In herds that we work with it is typical to have only 30% of mature cows showing estrus at 40 days postpartum, but up to 95% showing estrus by 90 days postpartum.

The only reliable way to assure that cows have had adequate time postpartum for cycling to begin is to enforce a short calving season (which of course corresponds to a short breeding season the previous year). At first glance it would seem that a longer breeding season would give cows more time to become pregnant. Figure 1 explains why this is not the case. Remember that in all cases we are working with a one-calf-per-year constraint. Therefore cows which conceive late in this season will be at a decided disadvantage for next year's breeding season. Circle A represents a one-year cycle in a beef herd with a 60-day calving period. Note that a cow calving on the first day of the calving season has until Day 140 to conceive. A cow which does not calve until the last day of the breeding season (Day 60), has only 80 days to conceive since the bull will be removed on Day 140. Circle B represents the same cycle except with 90-day calving and breeding seasons. A cow calving the first day of the calving season now has until Day 170 to conceive, a 30-day increase from an early cow in a 60-day situation. Note, however, that a cow that does not calve until Day 90 still has only until Day 170 (80 days) to conceive. Hence late calvers, those most likely, by far, to have difficulty becoming pregnant, are not given extra days to initiate cycling in the 90-day versus the 60-day program. Neither are late calvers in either program penalized by a shorter season except during a transition period when the length of the season is being reduced. A 60-day breeding season forces all cows to be earlier calvers since those not meeting the goal fail to conceive and are hence culled.

Getting cows to calve earlier has other major advantages. Probably the most important is that the average calf will be older. Since age of the calf is a major determinant of weight of the calf at weaning, early calving produces heavier average weaning weights. Figure 2 graphically illustrates this. If calves in a given setting gain 1.75 pounds/day from birth to weaning and are born in a typical pattern for a 63-day calving season versus a 105-day calving season, the result is a heavier calf. In this example the average calf is 24 pounds heavier and the total pounds of calf weaned from this 100-cow herd is equivalent to 4.5 extra calves. Early calving thus makes a substantial contribution to the second most important contributor to break-even cost: weaning weights. A beef herd with a shorter calving season is also more uniform so that management practices such as calving watches, vaccination, implanting, flushing, etc. can be more effectively applied. A more size-uniform group of calves also has considerable advantage in marketing.

Figure 2. Percent of calves born in each 21-day period and its effect on weaning weight and total weight marketed.



A herd with a prolonged calving season may achieve a shorter season by applying three principles. The three principles are: 1) moving cows back (getting a calving to calving interval of less than twelve months); 2) letting cows drift forward by extending the calving to breeding interval; and 3) culling some cows. By applying the other principles of reproductive management cows can, on the average, be "moved back" one month each year. Using this principle only, a continuously calving herd could remove the bull for one month the first year, two months the second and continue this practice until a 60-day season was achieved in ten years. More rapid progress towards a 60-day season can be made if cows that calve in the few months before the newly selected calving season are left to stand open for an extra period of time. Cows that calve many months away from the selected calving season may be culled as an alternative to either many years of being "moved back" a month at a time, or being left open for a long period. An individual plan must be formulated for each herd based on herd factors including existing calving pattern, potential for culling, management capabilities, etc. In most instances a calving season can be greatly reduced in length over a period of one to four years without large expenses from culling.

Age of the Cow

Heifers that have just calved for the first time represent a special challenge to a successful reproduction program. In addition to the demands that all beef cows have, these heifers are continuing to grow, and they have less body capacity and therefore consume less energy when fed high roughage rations. They are slower to return to estrus than mature cows.[11] Without special management considerations, an inordinate number of these heifers will be culled for reproductive inefficiency when they fail to conceive during the controlled breeding season. Those conceiving late become late calvers and therefore a detriment to continued reproductive efficiency.

While heifer management systems will not be treated in detail here, a successful program is reported by Spitzer et al. (1980). This program resulted in heifers and cows calving earlier over a five-year period and provided a 33-lb. increase in calf weaning weights. Basically the program provided for exposing considerably more heifers to bulls than would be needed as replacements. A 45-day breeding season was used and only heifers conceiving during this time period were used as replacements. Heifers were fed to reach predetermined target weights (when most heifers would have reached puberty) prior to the beginning of the breeding season. Such target weights vary between breeds since age of puberty is influenced by both weight and breed but are generally in the range of 65% to 70% of mature body weight. Having heifers reach these target weights also provides insurance against dystocia problems at calving. Heifers were placed with bulls 20 days earlier than the breeding season for the cow herd. (Some authors recommend 30 days). This system resulted in a group of first-calf heifers that were well grown, had calved early, had been selected for fertility and had extra post calving days to begin cycling before the second breeding season began.

Special care should be continued to these first-calf heifers after they are bred. Nutrition should be sufficient to allow them to reach 85% of mature body weight by calving. All of the factors discussed in this article for cows must be given extra consideration for the first calvers. In most instances this care is best accomplished by housing and managing these animals separately from the mature cow herd. This extra care will assure that these heifers, probably the group with the best genetics, will remain in the herd to make their contribution.

Body Condition at Calving

Body condition, essentially the body fat storage, is the third major factor influencing the time from calving to cycling. Table 2 summarizes data reported by Whitman et al.[9] correlating body condition at calving with percentage of cows showing estrus at various times postpartum. The effect of condition is significant. Note, for example, that by Day 60 postpartum 90% of cows in good body condition had shown heat while only 61% and 46% of moderate and thin cows respectively had shown heat. Even by 120 days after calving only 77% of thin cows had shown estrus.

Table 2. Body Condition at Calving and Heat after Calving

		Days After Calving							
Body Condition At Calving	No. of Cows	40	50	60	70	80	90	100	120
		% Showing Heat							
Thin	272	19	34	46	55	62	66	70	77
Moderate	364	21	45	61	79	88	92	100	100
Good	50	31	42	91	96	98	100	100	100

From: Whitman, R.W. (1975)·

A system of scoring cows for body condition based on an examination of the spine, short ribs and the appearance of the tail head area has been developed. This is summarized in Table 3. A score of **1 or 2** correlates with "thin", **3 or 4** is "borderline", **5** is "moderate", **6 or 7** is "good" and **8 or 9** is "fat". Dunn et al. (1983) reported high correlations between body condition score and carcass fat depth, percent carcass fat and total carcass energy.

Condition scoring cows when calves are weaned and at calving time allows one to begin managing this aspect. Weight gains required to achieve "moderate" to "good" body condition at calving have been described for each body condition score.

Even cows that already have adequate condition must gain about 100 pounds in pregnancy related tissues during gestation. Average daily gains can then be calculated and nutrition provided toward this end. Early calf weaning, especially of thinner cows, may be necessary. Provision of good quality pasture and supplementation of hay and pasture with concentrate or silage may be needed to aid cows in gaining sufficient condition. In general, condition should be put on cows before calving occurs. The great increase in energy demand of milking makes significant weight gains difficult in cows that have just calved with feedstuffs available on most beef cattle operations. Greatly increasing nutrition after calving also tends to stimulate increased milk production so that energy is used for milk production rather than body condition gains.

Table 3. CHARACTERISTICS DESCRIBING BODY CONDITION SCORES

Score	Characteristics
1,2	The spine and short ribs are sharp to the touch and can be distinguished visually.
3,4	The processes of the spine can be identified individually by touch. They feel rounded--not sharp and the space between the processes is less pronounced.
5	The processes can be felt with slight pressure. The ends feel rounded. Space between the processes can be distinguished only with firm pressure. Areas on either side of the tail head are filled.
6,7	The ends of the processes can be felt only with firm pressure. Spaces between the processes cannot be distinguished at all. Abundant fat cover round the tail head with some patchiness.
8,9	Bone structure cannot be felt at all. The tail head is buried in fatty tissue.

Suckling Inhibition of Estrus

Suckling has long been known to inhibit return to estrus. Cassida (1968) reported a 42-day difference in return to estrus for nursed versus non-nursed beef cows. Obviously, management practices and considerations dictate that calves must be reared by nursing cows.

Wiltbank and associates have developed a system that allows some escape from the inhibition of suckling. They found that removing calves from cows for 48 hours at the beginning of the breeding season, when coupled with a flushing program, significantly improved pregnancy rates. Calves experience almost no ill effects when provided with feed and water during the period. Individual cow responses to the flushing and calf removal treatment vary depending on time after calving and body condition. Cows 50 days after calving and in moderate body condition showed an increase of from 45% cycling with no treatment to 79% cycling with treatment. It should be noted that thin cows respond only minimally to flushing and 48-hour calf removal. Wiltbank's flushing technique involved feeding 10 pounds of corn/head/day 14 days prior to beginning of breeding and for 21 days thereafter.

Presence of Bull

Recent evidence suggests that the presence of a bull hastens the return to estrus in postpartum cows. The need to maintain a 60-day calving season would probably dictate that the use of such a bull be made only after the bull was rendered infertile by some technique such as those used to produce teaser bulls.

The Use of Hormones

Considerable study has been directed in recent years towards the use of exogenous hormones to increase the reproductive efficiency of cattle.

Estrus synchronization programs based on the use of prostaglandin products, while holding promise for use in genetic improvement programs because they facilitate the use of artificial insemination, impact little on overall reproductive efficiency. A one-dose prostaglandin-synchronization program shortens the cycle of about one-half of the animals in the herd by less than one-half of a cycle. Two-injection programs provide little or no shortening of the cycle. Prostaglandin products have no effect on cows that have not begun to cycle after calving.

For some time investigators had limited success in stimulating heat in cows using various combinations of exogenous steriods. More recently, a steriod treatment involving an injection of 3 mg of norgestomet is and 6 mg of estradiol valerate, coupled with implantation of a polymer containing 6 mg norgestomet is commercially available (Synchromate B®). The implant is removed after 10 days. This treatment has shown some efficacy in increasing cycling after calving. Most of this effect is limited to cows in "moderate" or "good" body condition. This effect is accentuated on cows in marginal body condition when the Synchromate B treatment is coupled with 48-hour calf removal. The coupling of Synchromate B and calf removal is now termed the "Shang" treatment.

More recently GnRH injections as part of the Ovsynch program have been documented to increase cycling in cows. These are now being coupled with progesterone given orally (MGA) or via a vaginal insert (CIDR-B).

Conception Rate

The second major factor known to influence reproductive efficiency in beef cattle is conception rate. If shortened breeding seasons are used, as advocated above, high fertility must be achieved to secure high pregnancy rates. Cows will only be serviced two or three times during a breeding season. Three major factors are known to influence fertility in beef herds (in the absence of major disease entities):

-Time of calving
-Weight changes in cows near breeding
-Use of fertile bulls

Time of Calving

Conception rates are known to increase for approximately 90 days after calving in cattle. All of the considerations of early calving become doubly important since days after-calving influences markedly both cycling and conception. One study reported conception rates at 39% from 0-30 days postpartum, 53% from 31-60 days postpartum, and 62% from 61-90 days postpartum. Considerations listed above to get cows to calve early (to enhance estrus cycle activity by the beginning of the breeding season) will produce an extra benefit in terms of reproductive efficiency by also having cows at a stage of the cycle where conception rates will be maximized.

Weight Changes near Breeding

Table 4 summarizes data on two groups of cows classified according to weight gain or loss during the time of breeding. Pregnancy rates are listed at 20 and 90 days after breeding and first service conception rates are also provided. Results from the first study showed that cows losing weight had a first service conception rate of 43% versus 67% for cows showing no weight change. Thin cows gaining weight in the second study achieved an 87% conception rate as compared with 46% conception rate for cows merely maintaining their weight. Twenty and 90-day pregnancy rates reflect these differences in conception.

The flushing procedures described under "Factors Affecting After-Calving Cycling" become more important since they also influence cow fertility by encouraging cows to gain weight at breeding. Lush spring pasture may be used for this flushing and, in fact, time of calving season may be chosen so that such pasture will be available. A good program for reproductive management involves matching the reproductive events to the nutritional resources that are available on a given farm. It should be remembered that short, new grass with low dry matter content may not provide extra energy. If breeding occurs before good grass is available, provision of nutrition to produce weight gains must be made.

Table 4. Effect of Weight Changes near Breeding on First Service Conception and Pregnancy Rates in Mature Cows

		PREGNANT (%)			
CHANGE	NO.	From First Service	After Breeding 20 days	After Breeding 90 days	Cows not Showing Heat (%)
Calving to breeding					
Losing weight	43	29		77	14
No change in weight	67	57		95	0
Difference	24	28		18	14
Weight change in thin cows Near breeding					
Gaining weight	87		--	100	0
No change in weight	46		--	70	15
Difference	41		--	30	15

From: Wiltbank, J.N. (1983)

Program to Improve Reproductive Efficiency

An understanding of the major factors influencing beef cattle reproduction performance allows the formation of a program to maximize reproductive efficiency. As with any program realistic goals must first be established. A goal of 95% of cows calving during a 60-day calving period is high but attainable. In order to achieve this 65-75% of the cows should calve in the first 21 days of the calving season. This necessitates 95-100% of the cows showing estrus in the first 20 days of the breeding season and conception rates of 70-80%. Obviously, this will require both high cow and bull fertility.

In considering the major factors contributing to high pregnancy rates (cycling, cow fertility and bull fertility) it must be remembered that the factors are multiplicative and not additive. For example, if a figure for number of cows becoming pregnant in the first 20 days of the breeding season is to be estimated, then values for percent cycling, cow fertility and bull fertility must be known. Suppose all three figures are 90%. The expected pregnancy percent is then 90% x 90% x 90%, or 72% pregnant--not (90% + 90% + 90%) divided by 3, or 90% pregnant cows. This means that one low factor has a very negative influence on the overall result. If, in the above example, cow fertility is only 50%, the expected pregnancy percent is 90% x 90% x 50%, or 40.5% pregnant cows, not (90% + 90% + 50%) divided by 3, or 77% pregnant. Overall performance will never be higher than the lowest variable.

All of these principles can be distilled into a reproductive program:

1. A 65-day breeding season is enforced.

2. A nutritional program to ensure that cows are in "moderate" or "good" body condition (BCS 5-6) at calving time begins.

3. A nutritional program to ensure that cows are gaining weight before the breeding season and for the first three weeks of the breeding season is used.

4. Use of hormones for estrous synchronization at the beginning of the breeding season which enhance cyclicity of cows.

5. Cows are bred to fertile bulls (scrotal circumference of >32 cm and >70% normal sperm).

6. Additional measures are used as needed to achieve high reproductive rates. Examples: Calves are removed from cows for 48 hours at the start of the breeding season. Teaser bulls are used to increase cyclicity.

Application Reproductive Principles on the Powell River Project

The Beef Cattle Program on the Powell River Project involves a herd of about fifty cows that are managed primarily on forages that grow in reclaimed strip mined lands. The following practices have been successfully employed in there management as pertains to reproduction:

- Breeding is carried out during a season beginning near the end of May so that calving will begin near the beginning of March. The breeding season lasts sixty-five days.
- These seasons take advantage of the natural high quality of the forages in the beginning of the grazing season to provide for a positive energy balance beginning a few weeks before the breeding season.
- Calves are weaned in the fall early enough so that cow body condition is maintained. If dry conditions dictate early weaning is practiced to provide for reduced nutritional diamond on the project. Stockpiled forages provide adequate nutrition during the winter so that cows maintain a body condition of 5 to 6 on average by calving time. Relatively limited supplementation of harvested forages in the form of hay has been sufficient to maintain body condition adequate for excellent reproductive outcomes.
- Cows are synchronized using the 5-Day CIDR protocol that involves the use of GnRH, the Eazi-Breed CIDR® and prostaglandin F2α at the beginning of the breeding season.
- Cows are artificially inseminated with frozen semen from high quality bulls using this timed-AI protocol.
- A single bull has been sufficient to do clean-up breeding following the AI and is placed with the cows about three days following the timed AI.
- The bull is subjected to a breeding soundness examination prior to the beginning of the breeding season and replaced if he fails to meet the standards set the American Society for Theriogenology.
- Replacement heifers are developed so that they have achieved at least 65% of mature size prior to the breeding season and then are managed as per the cows as described above.

Results of the Breeding Program at the Powell River Project

Parameter	Number of Cows	Number Pregnant	Percent Pregnant
2008			
Pregnant During the Breeding Season	50	47	94%
Pregnant to Artificial Insemination	49	26	53.1%
Pregnant to the First Natural Service Cycle	24	19	79.2%
Percent Open at the End of the Breeding Season	3	47	6 %
2009			
Pregnant During the Breeding Season	47	43	95.7 %
Pregnant to Artificial Insemination	47	28	59.6 %
Pregnant to the First Natural Service Cycle	19	13	68.4 %
Percent Open at the End of the Breeding Season	4 (incl. 2 abortions)	43	8.5%

Summary

Applying the principles of beef cattle reproductive performance has resulted in excellent outcomes at the Powell River Beef Cattle Project. These excellent outcomes have been achieved on forages produced under typical beef cattle practices on reclaimed strip-mined land. Nutrition has been adequate, with minimal hay supplementation to achieve high levels of reproductive performance. Artificial insemination has been successfully applied using a fixed-time synchronization protocol which requires minimum labor and has resulted in very acceptable pregnancy rates. Followed by a natural service period with a single bull overall pregnancy rates have been in the realm of ninety-five percent. Application of these principles will allow for profitable reproductive outcomes with reasonable inputs on operations in the coalfields areas of Southwest Virginia.

Project Coal to Electricity
2009 Summer Teacher Education Program

Barbara Altizer
Eastern Coal Council

Amy Gail Fannon
Powell River Project Research & Education Center

Project Summary

This week-long summer session offers teachers in grades 3-6 and earth science a unique opportunity to learn about the coalfields in Virginia and the economic impact on the State's economy. Designed to address the natural resource and earth science standards of learning, the session provides teachers first hand field experience with the extraction, preparation and utilization of coal. In addition, the regulatory requirements and global economy associated with coal were examined.

Agenda

JULY 12 – SUNDAY	
2:p.m. to 5:30p.m.	Check-In: Martha Randolph Hall, UVA-Wise
6:00 p.m.	Dinner: Cantrell Hall
	Welcome to the program: Barbara Altizer
JULY 13 – MONDAY	
7:00 a.m.	Breakfast: Cantrell Hall
8:00 a.m.	Depart for Field Trip (UVA Bus provided Monday – Thursday for all trips)
8:00 a.m. – Noon	Tony Scales, Geologist, Virginia DMME Local geologic structure and its impact on history & coal mining and post-mining land use opportunities for economic development
12 Noon to 1:00 p.m.	Lunch: PRP-R&EC
1:30 p.m. to 5:00 p.m.	Mike Thomas, Red River Coal Co, coal surface mining operations
5:30 p.m. to 7:30 p.m.	Dinner: (cook out) at PRP-R&EC
Sponsored by:	Alpha Natural Resources
	Guest Speaker: Mike Abbott, Public Relations Manager, Virginia DMME
JULY 14 – TUESDAY	
7:00 a.m.	Breakfast: Cantrell Hall
8:00 a.m.	Depart for Field Trip
8:00 a.m. to Noon	Underground Coal Mine tour – Dickenson Russell Mine
Noon to 1:00 p.m.	Lunch sponsored by: Dickenson Russell
1:30 p.m. to 5:00 p.m.	Moss # 3 Preparation Plant and Spectrum Coal Laboratory
6:30 p.m.	Wine tasting & dinner: David Lawson, MountainRose Vineyard Inc
	Guest Speaker: Charles "Dutch" Tubman, Norfolk Southern

Sponsored by: Norfolk Southern Corp

JULY 15 – WEDNESDAY

6:45 a.m.	Breakfast: Cantrell Hall
7:30 a.m.	Depart for Buchanan County
9:00 a.m.	CNX Gas Tour (coalbed methane gas), Claypool Hill, VA
11:00 a.m.	Consol Energy Buchanan Mine (longwall operation)
12 Noon	Lunch: hosted by Consol Energy
2:30 p.m.	**Dallas Sizemore**, Virginia Department Environmental Quality - Air Quality Standards, Jewell Resources Training Center
3:30 p.m.	Jewell Smokeless Coke Ovens
7:00 p.m.	Dinner: Breaks Interstate Park, sponsored by: CNX Gas and Jewell Smokeless Coal Co Guest Speaker: Phillip Puckett, Virginia Senate

JULY 16-THURSDAY

7:00 a.m.	Breakfast: Cantrell Hall
8:00 a.m.	Depart for Field Trip
8:00 a.m. to 12 Noon	Appalachian Power, Carbo Plant
12 Noon to 1:00 p.m.	Lunch: Appalachian Power, Carbo Plant
1:45 p.m. to 3:30 p.m.	Tour Dominion Energy Power Station site & Update
5:30 p.m. to 10:30 p.m.	Social & Dinner, John Fox Jr. House, Big Stone Gap Guest speaker: Herbert Wheary, Dominion Energy Sponsored by: Dominion Energy
Outdoor Drama --	Trail of the Lonesome Pine
Sponsored by:	Oliver Coal Sales

JULY 17 – FRIDAY

7:00 a.m.	Breakfast: Cantrell Hall
8:00 a.m.	Depart for Field Trip (Will take personal vehicles)
8:15 a.m. to 10a.m.	Joy Mining Machinery Re-build Facility, Duffield, VA
11:00 a.m.	Tony Scales: Tour Natural Tunnel
12: Noon	Lunch – Natural Tunnel
1:30 p.m.	Ray Ratheal: Eastman Chemical Company's Coal Gasification Plant, Kingsport, TN
3:00 p.m.	Discussion/evaluation of program with teachers Professional Development Certificates presented

Project Coal to Electricity

Program Evaluation

July 13 – 17, 2009

Section 1 - Activity Questions

1. The majority of the attendees found out about this program through co-workers that have attended and recommended it. All attendees verbally or in writing is recommending this program to co-workers of all subjects and have stated an overwhelming desire for a second week of the class.

2. Many of the attendees were interested in coal, the process of mining and production. Others teach energy and earth science and were interested for both classroom and personal reasons. There were art teachers that attended to be able to give a background of coal and the coal industry in order to have the knowledge and tools to share with their students.

Section 2 - Awareness Change Questions

3. Overall, how appropriate were the field trip activities? Very Appropriate

Please rate each field trip

A. Flag Rock – geology & land use
B. Powell River Project Research & Ed Ctr
C. Red River's Surface Mine
D. Paramont Underground Mine
E. Toms Creek Prep Plant
F. CNX Gas
G. Consol Longwall Mine
H. DEQ
H. Jewell Smokeless Coke Ovens
I. Appalachian Power plant
J. Dominion Energy Power Plant
K. Joy Mining rebuild facility
L. Eastman Chemical coal gasification

4. Overall, how appropriate were the evening programs?
Very Appropriate

Please rate each evening program

A. Mike Abbott, DMME
B. MountainRose Vineyard
C. Tom Rappold, Norfolk Southern
D. Breaks Interstate Park
E. Senator Phillip Puckett
F. Herbert Wheary, Dominion Energy
G. Trail of the Lonesome Pine

Section 3 - Knowledge Change Questions

5. As a result of this program, to what extent do you believe students will increase their understanding of the impact of coal on the Virginia economy? To A Great Extent

6. As a result of this program, to what extent do you believe students will increase their understanding of the coal industry's future impact on the Virginia economy? To A Great Extent

Section 4 - Practice Change Questions

7. To what extent will you incorporated the information gained during this program into lesson plans?

A. **Adapt material to existing lesson plans** Often, when subject correlates to appropriate chapters.
B. **Use material to create new lesson plans** Often, More time will be spent on coal related SOL's because there is more information and materials to share with students.

8. **What will be done differently regarding teaching as a result of participating in the program?** Materials and samples to use in classroom activities. "Show and Tell" materials. Incorporating energy resources unit into curriculum. Knowledgeable on the coal industry and better equipped to teach it in depth. Sharing knowledge and materials with co-workers so they will be better equipped to teach about coal as an energy source. In depth teaching of the coal industry in Earth Science and some topics of environmental Biology. Coal and gas production were low priorities in curriculum, attendees intend to increase knowledge, analyze, use critical thinking skills as it pertains to future energy sources as opposed to coal and gas as a relates to economic and political factors.

Section 5 - End Result Change Questions

9. **Has your ability to implement grade level Standards of Learning with SW VA coalfield examples improved as a result of your participating in the program?** Yes, To Some Extent

Exploring career opportunities in engineering, balances between economic needs and the environment. Increased knowledge of coal, the everyday uses of coal, and coal's impact on Virginia's worldwide trade. Enhanced knowledge of Virginia's natural resources.

10. **Do you believe this will result in students gaining a better understanding of the world around them than would be the case if this program were not offered?**

Yes, increased knowledge of coal, the everyday uses of coal, and coal's impact on Virginia's worldwide trade. Students often hear uninformed people speak negatively about the coal industry, an industry they know nothing about.

11. Additional comments/impressions/thoughts:
Attendees will encourage co-workers to attend next year. Attendees overall loved the program, it was well planned and laid out. Attendees "loved" the people involved. Barbara was an excellent guide/teacher. There should be a "coal class 102" a second year so they have an opportunity to come back and further explore coal, coals relationship to the environment and economics of coal producing areas. Attendees would like more time underground because a couple of hours does not allow enough time to really understand the concept.

Less late evening speakers, but do not change or take anything out of the program. More materials like the maps, as students are primarily visual learners. Artistic renditions of mining operations such as the picture at the conference room for the longwall mine.

Attendees should be allowed to revisit the topic every 2-3 years to compare/contrast the sights/sounds from the previous experience. Open the program to different teaching disciplines, including high school teachers as the information would benefit them as well.

Overall a fantastic program, eye opening to a number of misconceptions about energy production, mining, and reclamation. Attendees have repeatedly expressed a desire to learn more and revisit the same program as well as an option for a second year program.

ACKNOWLEDGMENTS/SPONSORS

Teachers can stay abreast of important topics and remain informed about relevant topics they need to address in the classrooms through quality educational efforts.

The Project: Coal to Electricity Energy Education Program would not be possible without the continued partnerships and interest of many individuals and sponsors. We want to acknowledge the following:

Alpha Natural Resources
Appalachian Power Co. - Carbo Plant
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Jewell Smokeless Resources
Joy Mining Machinery
Norfolk Southern Corporation
Oliver Coal Sales
Paramont Coal Corp VA LLC
Powell River Project
Red River Coal Company
Spectrum Laboratories
Virginia Department of Mines, Minerals & Energy

These industry partners have made it possible for educators to broaden their understanding of environmental issues related to coal, rail and power, to experience the coalfields with hands on opportunities, to appreciate the important role of coal in the Commonwealth of Virginia's economy, as well as the United States.