SPECIES RICHNESS ON FIVE PARTIALLY RECLAIMED KENTUCKY SURFACE MINES[1]

by

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Abstract. Floristic studies were conducted on five surface mines which were mined and reclaimed before the Surface Mine Control and Reclamation Act of 1977 (SMCRA). At the time of the inventories, these sites ranged from 12 to 25 years of age and from 2 to 14 hectares. The number of species planted on each mine at the time of reclamation ranged from 3 to 110. The mean species richness of these five sites at time of inventory was 313. The number of species on each mine was 2 to 12 percent below the number of species to be expected on areas of these sizes within the Mixed and Western Mesophytic Region. Approximately 82 percent of the mine floras were native species which is comparable to the proportion of native species in the total flora of Kentucky. Species richness of the mines was significantly correlated with mine area. Number of invading species was significantly correlated with median pH of mine soils. Each of these five mined sites contained one or more species on the Kentucky list of threatened or endangered plants. These mines provide baseline data which can be used in evaluating the effects of post-SMCRA reclamation procedures.

Additional Key Words: Land reclamation, mine flora, biodiversity, succession, rare species.

INTRODUCTION

There has been very little investigation into whether or not surface-mined lands, especially pre-SMCRA (Surface Mining Control and Reclamation Act of 1977, also known as Public Law 95-87), have developed floras which are different from unmined areas. Complete floras have been compiled on five coal surface mines in eastern Kentucky. Floristic lists exist for other mines in the eastern United States. However, these lists are incomplete because they were based on plot sampling or included areas not impacted by mining. The purpose of this paper is to report on characteristics of the complete floras on five coal surface mines in eastern Kentucky which are typical of mines reclaimed under pre-SMCRA rules. These sites are Fonde, Henderson Fork Road, and Log Mountain in Bell County; Lily in Laurel County; and Trace Branch in Rockcastle County.

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STUDY AREAS

The five mines for which floristic studies have been completed are representative in terms of geology, spoil, and topography of areas mined and reclaimed under rules in effect before SMCRA in southeastern Kentucky. Physical characteristics of the sites are shown in Table 1. The Lily and Trace Branch mines are in the Cumberland Plateau Section of the Appalachian Plateau Province, while the Fonde, Henderson Fork Road, and Lily mines are located in the Cumberland Mountains Section of the Appalachian Plateau Province (Fenne-man 1938). All sites fall within the Mixed Mesophytic Forest Region (Braun 1950). Mine elevations range from 350 to 870 meters and nearly all aspects are represented. The mines encompass five geologic formations and five different coal seams. Mine spoils range from extremely acid to mildly alkaline.

The Lily mine was an area mine while the other four mines were stripped on the contour. Four of these sites (all but Henderson Fork Road) were used for species trials or demonstration areas for "state of the art" mine reclamation at that time. Surface spoils were graded at all but the Henderson Fork Road site. Liming and fertilization were confined to relatively small trial plots at Fonde, Lily, Log Mountain, and Trace Branch. No fertilizer or lime was used at Henderson Fork Road. Reclamation plantings were established on 25 to 100 percent of the mine areas. Mine age at inventory ranged from 12 to 25 years (Table 1). The Log Mountain mine included a remined section so that a 13-year-old area was included within the 20-year-old mine.

METHODS

The floras of these areas were inventoried at two- to three-week intervals during growing seasons of the one- to two-year study periods (Thompson et al. 1984, Thompson and Wade 1991, Rafaill 1988, and unpublished works). Inventories covered the entire disturbed mined area at each site from the top of highwalls, to the benches, to the bottom of outslopes, and short haul roads.

Reclamation records of all but the Henderson Fork Road mine were maintained by the Northeastern Forest Experiment

Table 1. Description of Study Sites on Five Coal Surface-Mined Areas in Kentucky.

	Fonde	Henderson Fork Road	Log Mountain	Lily	Trace Branch
Type of Mine	Contour	Contour	Contour	Area	Contour
Elevation (m)	580	682	870	350	335
Local Relief (m)	520-700	550-915	550-880	330-370	280-390
Aspect	NE-NW	SW-W	W-NW	flat	W
Geologic Formation	Mingo	Hignite	Bryson	Breathitt	Breathitt & Lee
Coal Bed Mined	Mingo	Hignite	Red Springs	Lily	Corly Hollow
Mine Soil pH: median	4.0	4.8	6.4	4.1	3.8
range	2.8-5.9	4.2-5.3	4.8-7.7	2.7-6.7	3.3-4.4
Mine Area Planted	80%	100%	100%	25%	80%
Year Planted	1965	1963	1964-65 & 1971	1965-66	1975
Age at Inventory (Since Planting)	25	25	20, 13	18	12

Station, USDA Forest Service research laboratory at Berea, Kentucky. Soils data were obtained from other studies conducted on the mines. Soil pH was determined from 1:1 water extracts (Page 1982).

A Pearson correlation matrix was calculated to determine the interrelationships of species richness (number of species present), mine area, number of planted species, median weathered surface soil pH value, number of nonplanted species successfully invading each site, and mine age. The level of significance for all tests, simultaneously, is $P \leq 0.05$ using the multiple testing protection afforded by Bonferroni's inequality (Miller 1981).

Expected species richness of areas the size of these sites was determined using the species area curve $S = 272A^{0.113}$ derived for the combined Mixed and Western Mesophytic Forest Regions (Braun 1950) by Wade and Thompson (1991). A 95 percent confidence interval around the regression line was used to determine significance between expected versus observed species richness.

RESULTS

A taxonomic summary of the floras of these five mined sites shows that the number of species planted on the sites ranged from 3 to 110 (Table 2). Mean survival or persistence of planted species was 85 percent. Invasion of native and naturalized species significantly increased the numbers of established species on these sites. The mean species richness of these sites was 313 with a mean increase of 273 species since mining and reclamation. Mine floras included a mean of 82 percent native species which is comparable to the 84 percent native species in the flora of Kentucky (Browne and Athey 1992).

The Asteraceae and Poaceae were the most important families in terms of species richness, followed by the Fabaceae, Rosaceae and Cyperaceae (Table 3.) These plant families are the five largest listed for Kentucky (Browne and Athey 1992).

Comparison of species richness of the mined sites ranged 2-12 percent below that expected on unmined sites (Table 4 and Figure 1). These differences from the expected species richness were not statistically significant.

The correlation matrix (Table 5) showed that total number of species on the mines was significantly correlated with mine area. The number of successfully invading species was positively correlated with median mine soil pH.

All five of the mined sites contained one or more plant species listed by Warren et al. (1986) as threatened or endangered in Kentucky (Table 6).

Species richness on the mines had a linear relationship with mine area. The regression r^2 for untransformed mine species-area data was 0.957; while the r^2 for log-transformed data was 0.885. Regression models for both types of data are statistically significant (F-test, $P \leq 0.05$).

DISCUSSION

The majority of studies concerning plant species-area curves have supported stronger linear species-area relationships between log-transformed data than untransformed data. The reverse case, as found here, may be due to insufficient time since mining for a more "normal" species-area relationship to develop. While species richness on these sites is obviously influenced by the number of planted species, species richness at the time of inventory is most closely related to area. The correlation between number of invading species and number of planted species is very weak. This indicates that mined sites are developing species-area relationships similar to unmined areas. Baig (1992) found strong correlations

Table 2. Taxonomic Summary of Flora of Five Coal Surface-Mined Areas in Kentucky.

	Fonde	Henderson Fork Road	Log Mountain	Lily	Trace Branch
Families:	83	74	82	84	63
Genera:	190	183	230	210	170
Species:	298	284	360	350	272
Woody Species:	71	38	59	105	57
Trees:	47	25	41	67	34
Shrubs & Vines:	24	13	18	38	23
Herbaceous:	227	246	301	245	215
Native Species:	247	253	284	273	220
Species Planted:	31	3	25	110	30
Species Surviving:	26	3	22	78	24

Table 3. Important Families by Largest Number of Species on Five Coal Surface-Mined Areas in Kentucky.

Fonde		Henderson Fork Road		Log Mountain		Lily		Trace Branch	
Asteraceae	42	Asteraceae	54	Asteraceae	61	Poaceae	47	Asteraceae	43
Poaceae	34	Poaceae	33	Poaceae	39	Asteraceae	38	Poaceae	39
Fabaceae	14	Cyperaceae	16	Fabaceae	20	Fabaceae	33	Fabaceae	25
Rosaceae	13	Fabaceae	15	Cyperaceae	16	Rosaceae	21	Rosaceae	11
Cyperaceae	11	Rosaceae	13	Rosaceae	15	Cyperaceae	14	Cyperaceae	11

Table 4. Species-Area Relationships on Five Coal Surface-Mined Areas in Kentucky.

	Fonde	Henderson Fork Road	Log Mountain	Lily	Trace Branch
Area (ha):	7	2	14	14	2.5
Species Found:	298	284	360	350	272
Species Expected[1]:	340	294	367	367	302
Deviation	-12%	-3%	-2%	-5%	-10%

[1]Based on a species-area prediction equation for the combined Mixed and Western Mesophytic Forest Regions, $S = 272A^{0.113}$, where S = expected number of species, and A = area in hectares (Wade and Thompson 1991).

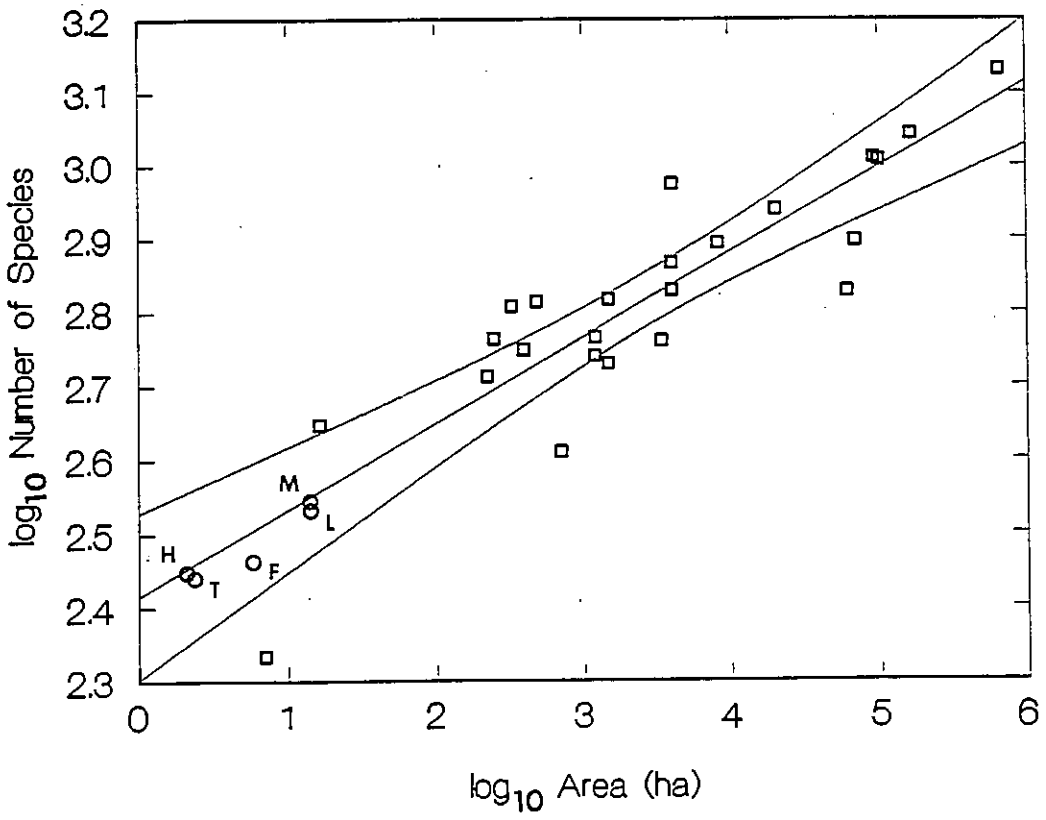

Figure 1. Species richness of five partially reclaimed Kentucky surface mines and other sites in the Mixed and Western Mesophytic Forest Regions. The center line is expected species richness; the outer lines are the 95 percent confidence interval. Key: H = Henderson Fork Road, T = Trace Branch, F = Fonde, L = Lily, M = Log Mountain.

Table 5. Pearson Correlation Matrix of Selected Variables on Five Coal Surface-Mined Areas in Kentucky.

	Number of Species	Area	Species Planted	Median Soil pH	No. Spp. Invading	Site Age
Number of Species	1.000					
Area	0.977[1]	1.000				
Species Planted	0.539	0.638	1.000			
Median Soil pH	0.603	0.458	-0.322	1.000		
No. Spp. Invading	0.719	0.604	-0.196	0.973[1]	1.000	
Site Age	0.039	-0.016	-0.327	0.234	0.325	1.000

[1]Correlation coefficients $\geq$ 0.953 are significant at P $\leq$ 0.05 using Bonferroni's inequality (Miller 1981).

Table 6. Threatened or Endangered Plant Species on Five Coal Surface-Mined Areas in Kentucky[1].

Mine	Species	Classification in Kentucky
Fonde	Scirpus fluviatilis (Torr.) Gray	threatened
Henderson Fork Road	Gentiana decora Pursh	threatened
Log Mountain	Liparis loeselii (L.) L.C. Richard	threatened
	Silene ovata Pursh	threatened
	Gentiana decora Pollard	threatened
Lily	Lobelia nuttallii Roem. & Shultes	threatened
	Cotinus obovatus Raf.[2]	endangered
Trace Branch	Hedeoma hispidum Pursh	endangered

[1] Warren et al. (1986)
[2] Planted and persisting in species trial plots (Plass 1975, Wade et al. 1985)

between species richness and area on mines older than 29 years, but not on mines less than 10 years old in the Rocky Mountains of Alberta.

The number of successfully invading nonplanted species was significantly and most highly correlated with soil median pH value. Cornwell (1971) and Glenn-Lewin (1979) have found similar species number-soil pH relationships on mine spoils.

The low correlation of species richness and number of successfully invading species with mine age was unexpected. Mine area and edaphic factors appear to have had a greater influence than time alone in determining species richness on these five sites. Strong correlations between number of invading species and age on mines ranging 2 to 50 years old was found by Baig (1992).

Because of the low number of observations, lack of significant correlation between other variable pairs should be interpreted as "correlation is not supported by the limited data available for this study."

Pre-SMCRA mine reclamation practices in the Appalachian coal fields created a variety of disturbance environments including highwalls, benches, wet areas, and outslopes. Mine soils can range from extremely acidic to slightly alkaline, very dry to continually saturated, and loose to extremely compacted. Soil fertility can vary significantly because of parent materials, patchy fertilization, and plant species effects such as nitrogen fixation, and differential element uptake and deposition in litter. Spoil depths can range from zero to several meters while textures and stone contents may be highly variable. Sites may be topographically protected or highly exposed with various aspects. This wide variety of disturbed physical environments, partially modified by reclamation plantings, has provided an extraordinary variety of easily invaded habitat niches for plant species. The relatively high edge-to-area ratios common to older contour mines may also lead to high

plant species invasion rates. Pockets of premining forest topsoils in reclamation forest plantings on mined sites can support "mesic rich woods" species. The species-area relationship also infers that many of the hundreds of plant species in the Appalachian flora, which are potential colonizers of many disturbance types, will not be found within the limited areas encompassed by these five mines.

Pre-SMCRA surface mines may be important habitats for certain rare plant species in the Eastern Kentucky Coal Field. There are numerous examples of rare species occupying refugia on mined lands in Europe (Bruns 1986, Palmer 1992, Sanderson 1992).

These results and the floras on which they are based will serve as a basis for future comparison of the effects of current, post-SMCRA land reclamation practices on developing mined-land floras. Unmined coal is immediately adjacent to all of these contour-mined sites. Any remining of these mined sites could allow later comparisons of pre-SMCRA:post-SMCRA reclamation technique effects on the same location and geological materials. Differences will be chiefly due to reclamation methods. Environmental factors distinguishing post-SMCRA from pre-SMCRA reclaimed sites are site hydrology (affected by topographic form and compaction) and environmental heterogeneity. Ecological inertia (Pielou 1991) on post-SMCRA sites also may restrict establishment of invading species because of of continuous, competitive herbaceous cover on highly fertilized mine soils. Wisheu and Keddy (1989) reviewed species richness-productivity data from 9 studies in diverse ecosystem types. They concluded, in general, that highest species richness is found in areas with intermediate levels of productivity. Low to moderate fertility of these mine soils may also contribute to the high species richness of these mined sites.

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