IS THERE A CHARACTERISTIC FLORA OF APPALACHIAN PRE-SMCRA SURFACE MINES?[1]

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Abstract: Within a landscape, specific physical habitats (shale barrens, limestone glades, acid bogs, etc.) are often characterized by their floras – the collection of plant species or taxa that inhabit them. Composition of some floras can be unique because their environments have characteristics that allow colonization by some taxa and select against colonization by others. A significant proportion of Appalachia was mined with limited reclamation before the Surface Mine Control and Reclamation Act of 1977 (SMCRA). Successional processes have, over time, enriched the plant communities on these mines to the point that their taxonomic richness is comparable to similar unmined areas. But are the floras of these mines distinctive unto themselves? Five mines in eastern Kentucky have been completely inventoried and we use the species lists to determine whether pre-SMCRA mines have their own distinctive flora. Altogether, these five mines supported 617 vascular plant taxa or 18 percent of the documented flora of Kentucky. Species richness of the individual mines ranged from 272 to 360 taxa. There were 85 core taxa (species present on all five mines, 13.8 percent of total). Peripheral taxa (present more than half but not all mines) numbered 195 (31.6 percent) and casual taxa (present on half or less of the mines) numbered 337 (54.6 percent). Pair-wise Sørenson's indices of similarity (the proportion of one mine flora also found on another) ranged 0.48-0.75. We list core and peripheral taxa that were found on there pre-SMCRA mines, but we do not conclude that pre-SMCRA surface mines have their own distinctive flora.

Additional Key Words: succession, revegetation, floristics, restoration, reclamation, biodiversity

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Introduction

Within a landscape, specific physical habitats (shale barrens, limestone glades, acid bogs, etc.) are often characterized by their floras – the collection of plant species or taxa that inhabit them. Composition of some floras can be unique because their environments have characteristics that allow colonization by some taxa and select against colonization by others. A significant proportion of Appalachia was mined with limited reclamation before the Surface Mine Control and Reclamation Act of 1977 (SMCRA). Successional processes have, over time, enriched the plant communities on these mines to the point that their taxonomic richness is comparable to similar unmined areas. But are the floras of these mines distinctive unto themselves?

In this paper we synthesize the floras of five completely inventoried surface mines in eastern Kentucky to determine:

- Is there a distinctive, characteristic flora of pre-SMCRA mines?
- What is the importance of exotic species in mine floras and can they become a problem?
- What is the importance of plantings to enhance mine diversity?
- How important is habitat diversity in promoting plant biodiversity on the mines?
- What is the role of continuing disturbance in mine species diversity?

Methods

We combined the datasets from complete inventories of five pre-SMCRA surface mines that were reclaimed or partially reclaimed from 1963-1972. We used these data to synthesize the flora for pre-SMCRA mines in Eastern Kentucky. These mines are described in Table 1 and their floristic summaries are in Table 2.

We divided the taxa into three categories. The *core flora* are taxa that are found on all of the inventoried areas. *Peripheral taxa* are those that are found on more than half but not all of the areas. *Casual taxa* are those with a frequency of half or less than half of the areas.

We compared compositional similarities among the mines and habitats of the mines using Sørenson's and Jaccard's indices of similarity and correlation of taxonomic abundance. Sørenson's index of similarity is

$$IS_S = 2c/(F_n + F_m) \quad \textbf{(1)}$$

Table 1. Characteristics of five pre-SMCRA surface mines in eastern Kentucky that have complete botanical inventories.

Mine Name	Mine Type	Mine Age When Inventoried	Aspect & Elevation (m)	Area (ha)	Published Flora & Description
Log Mountain	contour	14 & 21	W-NW 850-890	14.2	Thompson et al. 1996
Fonde	contour	24	NW-NE 560-562	7.3	Wade and Thompson 2002
Henderson Fork Road	contour	38	W-SW 686	3.4	Rafaill and Thompson 2002
Trace Branch	contour	12	W 278-386	2.5	Thompson and Wade 1991
Lily	area	18	flat	14.0	Thompson et al. 1984

Table 2. Floristic summaries of five pre-SMCRA surface mines in eastern Kentucky that have complete botanical inventories.

Mine Name	Taxonomic Richness	Relative Richness	Exotic Taxa	Percent Exotic Taxa	Planted Taxa
Log Mountain	360	0.98	74	20.6	25
Fonde	298	0.88	53	17.7	31
Henderson Fork Road	312	1.00	41	13.1	3
Trace Branch	272	0.90	52	19.1	30
Lily	350	0.95	77	22.0	110

where F_n and F_m are the taxonomic richness of a pair of floras and c is the number of taxa in common to them (Magurran 1988). IS_s describes the mean proportion of one flora that is found in a second flora and vice versa. The index changes linearly as floras change similarity. Jaccard's index of similarity is defined as

$$IS_J = c/(F_n + F_m - c) \qquad \textbf{(2)}$$

(Magurran 1988). Jaccard's index describes the proportion of all taxa found in two floras that are common to both. IS_J changes non-linearly as similarity among a pair of floras changes. Many botanists use Jaccard's index for comparison of floras (Kent and Coker, 1992). We calculated IS_J for use of those who prefer it, but we will not discuss it in this paper as use of it leads to the same general conclusions.

The correlation of taxa abundances (CTA) is the nonparametric Spearman's rank correlation of taxa abundance (CTA) values (converted to numerical form) in common among pairs of floras (Brown and Chambers, 1981). CTA indicates the overall consistency of species abundance or importance among several floras. Because abundances for several hundred species are spread among only five abundance classes and thus producing a large number of ties in the rank analysis, we use CTA as an index of similarity without a test of statistical significance. The abundance classes used on the contour mines are similar but not exactly the same (Table 3). Even so, the use of correlation of abundance data gives more compositional information than mere presence alone. CTA can have values ranging from -1 to 1. Negative values are unusual but can occur when two floras have few species in common and their orders of abundance are reversed. The same indices used for intermine comparisons of floras are used for intramine comparison of habitats.

Relative richness was determined by dividing the number of taxa found in a botanical inventory by the number of taxa expected to be in an area of that size as calculated by a regional species-area curve. The species-area curve for the Mixed and Western Mesophytic Forest Regions as delineated by Braun (1950) is

$$R_e = 272(A^{0.113}) \qquad \textbf{(3)}$$

where R_e is the expected richness and A is the surveyed area in hectares (Wade and Thompson 1991).

Abundance data available for the five mine inventories varied (Table 3 and 4). The Lily inventory noted only species presence on the mine overall. At the time of inventory, abundance was rated by habitat (bench, highwall, outslope, road, and wet areas) on Log Mountain and Trace

Branch mines. On Henderson Fork Road and Trace Branch mine, overall mine data was presence-absence. But since habitat abundance class was recorded, we set the mine abundance class value for each species to its highest abundance class value among the included habitats. Thus, when a species was rated "abundant" it means the species was abundant in one or more important habitats on the mine, though not necessarily on the entire mine.

Table 3. Abundance classes used in botanical inventories of surface mine in eastern Kentucky.

Mine	Abundance	Definition
Log Mountain	Abundant	Thousands of individuals or colonies
	Frequent	Hundreds of individuals or colonies
Fonde	Occasional	26 - 100 individuals or colonies
	Infrequent	6 - 25 individuals or colonies
	Rare	1 - 5 individuals or colonies
Henderson Fork Road	Abundant	Dominant or co-dominant (Thousands of individuals or colonies)
	Frequent	Easily or generally encountered but not dominant (hundreds of individuals or colonies)
	Occasional	Widely scattered by not difficult to locate (31 to 100 individuals or colonies)
	Infrequent	Found in several locations but difficult to locate (6 - 30 individuals or colonies)
	Rare	Difficult to find and limited to one or two localities (1-5 individuals or colonies)
Trace Branch	Frequent	More than 100 individuals or 26 colonies
	Occasional	26 - 100 individuals or 6 - 25 colonies
	Infrequent	6 - 25 individuals or 3 - 5 colonies
	Rare	1 - 5 individuals or isolated colonies encountered once or twice

Table 4. Characteristics of species abundance data available for each mine.

Mine	Mine Overall	By Habitat

Log Mountain	categorical abundance	categorical abundance
Fonde	categorical abundance	presence
Henderson Fork Road	presence (abundance is derived)	categorical abundance
Trace Branch	Presence (abundance is derived)	categorical abundance
Lily	presence	none

Pearson correlations were used with data from all five mines to test for significant relationships of mine age with species richness and number of species plant with mine richness. The level of significance for statistical tests was set at $\alpha = 0.05$.

Results

At the times of inventories, the taxonomic richness of the five mines ranged from 272 to 360 (Table 2). The total taxa found on all mines were 617. Based upon a regional species-area curve (Wade and Thompson, 1991) for the Mixed and Western Mesophytic Forest Regions (Braun, 1950), the relative richness of the five mines was 0 to 12 percent below that to be expected on unmined areas of the same size (Rafaill and Thompson, 2002).

The core flora of the mines numbered 85 taxa (13.8 percent of the taxa on all mines) and peripheral flora numbered 195 (31.5 percent)(Table 5, and Appendices I and II). Casual taxa on the five mines numbered 337 (54.6 percent). Exotic species comprised 18.0 percent of the overall mine flora and constituted similar proportions of the core, peripheral, and casual taxa.

Intermine similarities based upon Sørenson's index of similarity (IS_S) ranged 0.48-0.75, and correlation of taxa abundance (CTA) ranged 0.22-0.52 among the four mines for which abundance data was given or derived (Table 6).

Table 5. Summary of native and exotic components of core, peripheral, and casual taxa of five pre-SMCRA surface mines in eastern Kentucky that have complete botanical inventories.

Numbers in parentheses are the proportion in percent of the total flora of 617 taxa.

Taxa Status	Total Taxa	Number Native	Number Exotic
Core	85 (13.8%)	67 (10.9%)	18 (2.9%)
Peripheral	195 (31.6%)	161 (26.1%)	34 (5.5%)
Casual	337 (54.6%)	278 (45.1%)	59 (9.6%)
Total	617 (100%)	506 (82.0%)	111 (18.0%)

Table 6. Intermine similarities of five pre-SMCRA surface mines in eastern Kentucky that have complete botanical inventories. Order of data in the table is IS_s/ ISj/CTA.

	Fonde	Henderson Fork Road	Trace Branch	Lily
Log Mountain	0.63 0.45 0.44	0.75 0.60 0.46	0.56 0.39 0.52	0.53 0.36 –
Fonde		0.63 0.46 0.46	0.54 0.37 0.34	0.51 0.34 –
Henderson Fork Road			0.52 0.35 0.33	0.48 0.31 –
Trace Branch				0.58 0.46 –

The mean IS_S among the mines = 0.573.

Taxonomic richness of the mines was not significantly correlated with the number of species that were planted on the mines ($r = 0.41$, $P = 0.49$), nor was there any correlation of total richness with mine age ($r = 0.11$, $P = 0.86$). The great majority of taxa on the mines were rated as being at the low end of the abundance scales – occasional, infrequent, or rare (Table 7). The same was true of species abundances in the different habitats of the mines.

Table 7. Proportional distribution (%) of native, exotic, and all vascular plant taxa among abundance classes on four inventoried mines in eastern Kentucky.

Abundance class	Mine											
	Log Mountain			Henderson Fork			-----Fonde-----			Trace Branch		
	N	E	all	N	E	all	N	Et	all	N	Et	all
Abundant	3	5	4	1	2	1	2	4	2	–	–	–
Frequent	8	4	7	20	5	18	7	2	6	7	27	15
Occasional	19	33	22	36	37	36	20	11	19	23	19	25
Infrequent	34	24	32	27	27	27	38	35	38	42	38	39
Rare	36	33	35	16	29	18	33	48	36	36	15	21

Using the habitat abundance data available for the Log Mountain and Trace Branch mines, we found that interhabitat flora compositional similarities on the mines varied considerably (Tables 8 and 9). Inter-habitat IS_S ranged 0.10 to 0.75 on Trace Branch and 0.07 to 0.46 on Log Mountain. CTA ranged 0.20 to 1.00 on Trace Branch and -0.46 to 0.57 on Log Mountain.

Available habitat abundance data allowed intermine comparisons for only Log Mountain and Trace Branch (Table 10). The floras of similar habitats on the two mines were quite dissimilar with IS_S ranging 0.04 to 0.29, and CTA ranging -0.02 to 1.00. The 1.00 value is based on only three species in common to wet areas on the two mines.

All habitats on the four contour mines had a suite of taxa unique to only one habitat (Table 11). The habitat-unique species ranged from 1 to 23 percent of the mine floras. On the four contour mines, the overwhelming majority were found in only one or two habitats (Table 12). Only three species on Trace Branch mine were found in all habitats. The majority of plant taxa were found on only one or two mines (Table 13) and the core flora of the five inventoried mines were comprised of only 85 out of 617 taxa.

Table 8. Floristic similarities of habitats on the Trace Branch mine. The main diagonal is species richness. Order of data above the main diagonal is IS_S/, IS_J,/ CTA. The numbers of

taxa in common are given below the main diagonal.

	Bench	Outslope	Highwall	Wet Areas	Road
Bench	**158**	0.52 0.36 0.32	0.29 0.17 0.20	0.11 0.06 0.71	0.75 0.60 0.55
Outslope	81	**151**	0.36 0.22 0.32	0.13 0.07 0.41	0.50 0.34 0.42
Highwall	29	35	**41**	0.10 0.05 1.00	0.32 0.19 0.14
Wet Area	11	12	4	**41**	0.13 0.07 0.59
Road	113	74	29	12	**143**

Table 9. Floristic compositional similarities of habitats on the Log Mountain mine. The main diagonal is species richness. Order of data above the main diagonal is IS_S, /IS_J,/ CTA. The number of taxa in common is given below the main diagonal.

	Bench	Outslope	Highwall	Wet Areas	Road
Bench		0.41	0.46	0.17	0.37
	262	0.26	0.29	0.09	0.23
		0.58	0.57	0.57	0.29
Outslope	74		0.42	0.08	0.25
		97	0.27	0.04	0.11
			0.10	-0.46	-0.10
Highwall	84	43		0.07	0.19
			107	0.04	0.10
				0.25	0.25
Wet Area	27	6	6		0.11
				60	0.06
					0.44
Road	67	24	19	9	
					97

Table 10. Compositional similarities of floras in similar habitats on Trace Branch and Log Mountain mines.

Index	Bench	Outslope	Highwall	Wet Areas	Road
IS_S	0.29	0.19	0.04	0.24	0.23
IS_J	0.17	0.10	0.02	0.13	0.13
CTA	-0.02	0.05	1.00	0.15	0.55

Table 11. Proportions of mine floras found only in one habitat on four Kentucky partially reclaimed pre-SMCRA mines.

	Log Mountain	Henderson Fork Road	Fonde	Trace Branch	Mean
Bench	0.23	0.23	0.16	0.09	0.178
Outslope	0.04	0.09	0.10	0.17	0.100
Highwall	0.04	0.12	0.10	0.01	0.068
Wet Areas	0.07	0.19	0.05	0.08	0.098
Road	0.05	–	0.06	0.06	0.057
Sum	0.43	0.63	0.47	0.41	0.485

Table 12. Proportional distribution of floras among multiple habitats on surface mines. The proportion of the each mines flora is shown above the actual number of species. Species recorded as present on the mines but not associated with a listed habit are omitted.

	Log Mountain	Henderson Fork Road	Fonde	Trace Branch
Number of taxa in 5 habitats	0.00 0	n.a.	0.00 0	0.01 3
Number of taxa in 4 habitats	0.03 12	0.00 1	0.01 2	0.10 26
Number of taxa in 3 habitats	0.14 49	0.06 19	0.18 54	0.15 40
Number of taxa in 2 habitats	0.37 130	0.29 92	0.35 103	0.35 94
Number of taxa in 1 habitat	0.43 163	0.63 200	0.47 139	0.41 108

Table 13. Distribution of taxa across the five inventoried mines in eastern Kentucky

Distribution of Taxa	Proportion of the total flora of all five mines (%)
Found on 5 mines	13
Found on 4 mines	12
Found on 3 mines	19
Found on 2 mines	23
Found on 1 mine	33

Discussion

Regardless of whether the mine floras are examined at the level of the habitat or the entire mine, the abundances of most taxa are concentrated in the lower abundance categories (Table 7). This is common in natural communities as well. Ugland and Gray (1982) report that when species are log-normally distributed, rare species will constitute approximately 65 percent of the total, intermediate species will be about 25 percent of the total, and the abundant species will be about 10 Percent. Martin (2000) analyzed data collected using a five-class abundance scale in a secondary forest by Wade et al. (unpublished) and found similar distributions. The mine floras used four- and five-class abundance scales and we also saw similar patterns.

Is There an "Appalachian Mine flora"?

These five mines in eastern Kentucky have developed highly diverse floras with a relative richness that ranged 0 to 12 percent below what would be expected in unmined areas of the same size in the Mixed Mesophytic Forest Region in which these mines are located (Table 2). The total taxonomic richness (617) of the mines is 18 percent of the documented flora of Kentucky (Browne and Athey, 1992).

A small minority of the total flora of the surface mines is found on all mines. The core flora is 13.8 percent of the total taxonomic richness, and summed with the peripheral flora (those found on the majority of the mines, 31.5 percent), these two categories still do not comprise the majority of the mine taxa. Overall species relative abundances ranks are core > peripheral >

casual. The species that are present on the most mines also tend to be more abundant on those mines.

Comparing the Log Mountain and Trace Branch mines (the only two mines with habitat-wise abundance values), we find that similar habitats on the two mines have quite dissimilar floras (Table 10). If the floras of these habitats are random subsets of the numerous taxa in Appalachia that can become established in such environments, we would expect a low similarity unless the habitats on the mines were such that they excluded most potential invaders. Low similarity, such as we see here (IS_S range 0.04 to 0.29), indicates that the number of potentially invasive species for the mine environments is greater than the numbers found on any one mine. All of this indicates that the mines as a group, not just each on its own merits, are floristically diverse. Add consideration of the large casual component of the mine floras – the majority of the species on each mine – and it is difficult to defend an idea that there is a characteristic flora of Appalachian surface mines that is fundamentally different from their surroundings.

We consider mine floras to be segregates of the regional flora just as Braun (1950) considered the white oak-beech forest to be a segregate within the Mixed Mesophytic Forest in the Cumberland Mountains. A segregate is what is left after some taxa have been eliminated from a more extensive flora by environmental factors, such as the environmental conditions of an upper slope or a surface mine.

Reclamation plantings and later diversity

Although the number of species planted on these mines varied considerably, the species richness of the mines at the time of inventory was not significantly correlated with the number of species planted ($r = 0.41$, $P = 0.49$). Planted species may act as nurse species or facilitators of plant succession (Luken 1990). Ground cover species planted or arriving with mulch can suppress the establishment of some native species (Wade, 1989; Wade and Thompson, 1990; Luken, 1990; Holl and Cairns, 1994; Skousen at al., 1994; Torbert and Burger, 2000; Holl, in press). Many of the species planted on the mines, especially at Lily, were in species trial plots that did not cover extensive areas. Other factors such as diversity of habitats and proximity to sources of propagules apparently swamped the effects of planted diversity. In contrast, Schladweiler and Vance (1996) and Tierney and Wade (1998) found species richness of mines in the western US to be significantly related to species richness of the seed mixes used for reclamation and the size of the reclaimed area through the species-area relationship. Given enough time and adequate sources of propagules, richness of Appalachian pre-SMCRA mines may approach that predicted by the regional species-area relationship.

Diversity in initial plantings may also provide later-developing diversity. Ashby (1964) found differences in succession under black locust and shortleaf pine plantations on mine spoils in the mid-Western US. A later study also found that species of planted trees on mined sites had differential effects on invading tree species (Ashby et al. 1980).

Exotic species

In many of these early plantings on surface mines, exotic species were tested for their ability to establish and be productive on surface mines. Use of exotic species is now considered less desirable. There also is some concern about the invasibility of surface mines by naturalized exotic species and trepidation that these will become a problem – a few such as *Rosa multiflora* and *Elaeagnus angustifolia* have already become so on other mines.

Browne and Athey (1992) list 15.5 percent of the Kentucky flora as being exotic. The floras of all but the Henderson Fork Road mine had a greater proportion of exotic species, but the overall relative abundances of native and exotic species were similar. Exotics as a proportion of the total flora of each mine were negatively correlated with mine age ($r = -0.872$, $P = 0.047$). Given enough time, forest canopy closure should lead to expulsion of many shade-intolerant exotic species on these mines. Although there is potential for exotics to become significant proportions of mine floras, this problem can be minimized by exclusion of exotics from reclamation planting mixes, use of certified seed of native species, and clean mulch.

The importance of habitat diversity

Habitat diversity plays a large role in promoting the development of plant diversity on the surface mines. On the four contour mines, a large proportion (mean = 48.5 percent) of the floras were unique to only one habitat on each mine (Table 11). Although the number of species unique to any given habitat on a mine may be low, their proportional sum is a significant proportion of each of the mine floras. The fact that 82.5 percent of the taxa are found in at most two habitats on each mine reinforces this idea (Table 12).

The benches were the largest habitats on the contour mines and they contained the richest floras. Summing and adding the other smaller, more specialized habitats expanded the bench floristic lists a mean of 69 percent.

Within the Log Mountain and Trace Branch mines where abundance data for individual habitats was available, the IS_S among the habitats were generally low with means of 0.32 and 0.25, respectively (Tables 8 and 9). The benches and outslopes are the largest habitats on pre-SMCRA mines. Tables 8 and 9 show how compositionally dissimilar other habits are when compared to them. The order of importance of species in common may even be generally reversed when the number of species in common is low. Using data from these two mines it is clear that the wet areas are least similar to the benches and outslopes based upon their species composition.

All of the mines we inventoried contained one or more taxa, totaling six, that are state-listed as threatened, endangered, or of special concern in Kentucky (KSNPC, 2000)(Table 14). *Liparis loeselii*, *Scirpus fluviatilis*, and *Lobelia nuttallii* were found in wet areas. *Gentiana decora* was found on mesic bench sites at two mines. *Hedeoma hispidum* was found in dry, relatively disturbed soils under pine overstory on a bench. *Silene ovata* was found in an outslope habitat. The variety of habitats present on pre-SMCRA surface mines is important not only for mine diversity but also for providing refugia for state-listed species (Thompson et al., 1996; Rafail and Thompson, 2002; Wade and Thompson, 2002).

<u>The role of continuing disturbance</u>

Continuing disturbance occurs at all four of the contour mines because of the wasting of highwalls. The vertical highwalls have slumped or caved to an approximately 45^{o} angle since the time of initial reclamation. This continual wasting provides new open spaces every year for plant invasion and establishment.

The mine roads at Log Mountain, Fonde, and Trace Branch are still traveled and disturbed by local citizens driving four-wheel drive and off-road vehicles. This traffic disturbs the soil and often creates ruts that impound water, some of which is held for significant periods of time. All this provides specialized habitats and new ground for plant invasions. We also strongly suspect that propagules of some plant species are deposited in the road habitats with mud dropped from motor vehicles.

Table 14. State-listed taxa on five eastern Kentucky surface mines.

Mine	Listed Species	Status	Habitat
Log Mountain	*Gentiana decora*	special concern	bench
	Liparis loeselii	threatened	wet area
	Silene ovata	threatened	outslope
Henderson Fork Road	*Gentiana decora*	special concern	bench
Fonde	*Scirpus fluviatilis*	endangered	wet area
Trace Branch	*Hedeoma hispidum*	threatened	bench
Lily	*Lobelia nuttallii*	threatened	wet area

<u>The importance of study methods</u>

Study methods have great influence on study results. Thompson et al. (1984) randomly placed experimental transects and plots outside planted areas on the Lily mine and captured 89 species (39 percent) out of the 350 species (including 78 persisting planted). Similarly, a plot study at the Fonde mine captured 39 percent of the flora (Thompson and Wade, 2000). Species rated infrequent or rare are increasingly missed by sampling studies (Fig. 1). Most of the taxa in these mine inventories were rated occasional, infrequent, or rare (Table 7). Besides undercapture of less common species, sampling studies can underestimate Sørenson's and Jaccard's indices of similarity (Martin, 2000).

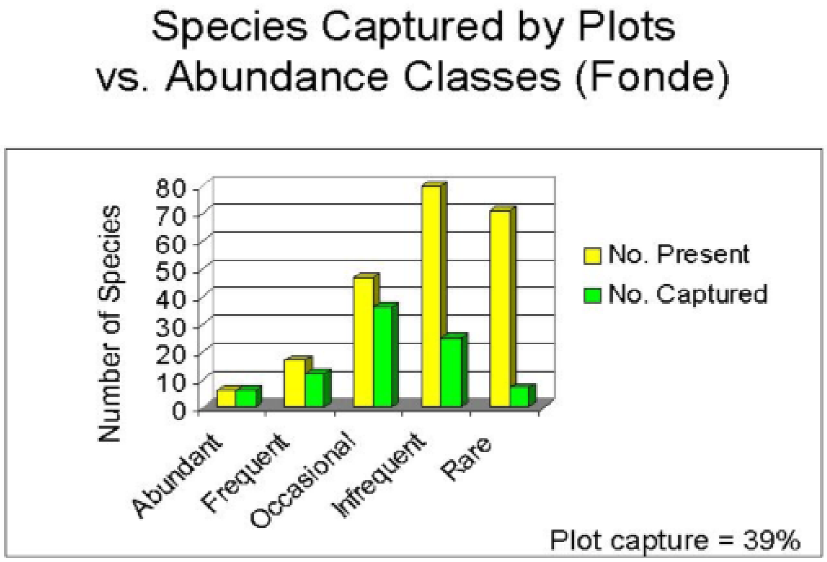

Figure 1. Species captured by plots in a vegetation study at the Fonde mine versus their abundance as determined by a complete floristic inventory.

Floristics questions are best answered by floristic studies that involve complete inventories based upon multiple visits that completely traverse the areas in question and pay particular attention to ecotones, unusual habitats, and disturbed areas. Vegetation studies, however, are generally plot based and avoid ecotones, unusual habitats, and disturbed areas. Both types of studies are useful and we suggest that combinations of both study types on post-SMCRA mines are necessary to get data that is comparable to existing floristic and vegetation studies.

Looking forward

We are here synthesizing floras of pre-SMCRA mines. It is expected that floras of post-SMCRA mines will be somewhat different overall and reduced in their biodiversity because of aggressive seed mixtures, some of which are exotic, but no intensive inventory studies of these new mines have been undertaken.

The floras of these pre-SMCRA mines demolish any idea that surface mines are necessarily distinctive in the Appalachian flora except as local segregates of the regional flora. These inventoried mines show us that near normal biodiversity are possible on mined lands. It is up to researchers, regulators, and reclamationists to determine whether post-SMCRA mines can be equally diverse, and if not, to devise methods of promoting and enhancing biodiversity in the post-SMCRA environments.

Conclusions

During 12 to 38 years of succession after reclamation, five inventoried, pre-SMCRA surface mines developed vascular plant floras that were only 0 to 12 percent less species-rich than would be expected in areas of the same size in this region. These five mines contained 18 percent of the known flora of Kentucky.

Core and peripheral flora of the mines constituted only 13.8 and 31.5 percent of the total mine flora, respectively. Taxa found on more surface mines tend to be among the more abundant on the mines on which they are found.

Taxonomic richness of the mines was neither significantly correlated with mine age nor number of species planted. Habitat diversity on the mines contributes greatly to both overall taxonomic richness and the role of these mines as refugia for state-listed species.

The majority of species in the mine floras were found on only one or two mines and only in one or two habitats on those mines.

Exotic species totaled 18.0 percent of the combined mine floras compared to their proportion in the flora of Kentucky, 15.5 percent. The proportion of exotics in the total mine floras was inversely correlated with mine age.

Exotic species comprised a somewhat larger proportion of the floras of four out of five of these mines than are found in the Kentucky flora as a whole, but we do not believe that exotic species on the mines are potential problems, with a few exceptions.

The floras of these mines appear to be segregates of the regional flora rather than expressions of a distinctive mine flora.

Biodiversity on mined lands can be enhanced by construction of dissimilar habitats using variation in topography, water availability, soils, initial plantings, and occasional modest disturbance.

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Appendix I

Core Taxa of Five Surface Mines in Eastern Kentucky

Exotic Taxa
Agrostis gigantea Roth.
Barbarea vulgaris R. Br.
Cardamine hirsuta L.
Dactylis glomerata L.
Daucus carota L.
Digitaria ischaemum (Scribn.) Muhl.
Echinochloa crusgalli (L.) Beauv.
Festuca elatior L.
Lespedeza cuneata (Dum.-Cours.) G. Don
Lespedeza stipulacea (Maxim.) Makino
Melilotus alba Medikus
Plantago lanceolata L.
Poa pratensis L.
Prunella vulgaris L.
Rosa multiflora Thunb.
Rumex crispus L.
Taraxacum officinale Weber
Veronica arvensis L.

Native Taxa
Acer rubrum L.
Agrostis perennans (Walt.) Tuckerm.
Ambrosia artemisiifolia L.
Andropogon virginicus L.
Asplenium platyneuron (L.) Oakes
Aster pilosus Willd.
Bidens aristosa (Michx.) Britton
Carex vulpinoidea Michx.
Chamaecrista nictitans (L.) Moench.
Clematis virginiana L.
Coreopsis major Walt.
Cornus florida L.
Desmodium paniculatum (L.) D.C.
*Eleocharis ovata (*Roth) Roemer & Schultes
Epilobium coloratum Biehler
Erigeron annuus (L.) Pers.
Eupatorium fistulosum Barratt
Eupatorium serotinum Michx.
Galium aparine L.
Galium triflorum Michx.
Hedyotis purpurea (L.) Torr. & Gray
Hieracium gronovii L.
Hypericum punctatum Lam.
Juncus effusus L. var. solutus Fern. & Wieg.
Juncus tenuis Willd.
Juniperus virginiana L.
Lactuca canadensis L.
Liriodendron tulipifera L.
Lobelia inflata L.
Lycopodium digitatum A. Braun
Lysimachia quadrifolia L.
Nyssa sylvatica Marsh.
Oxydendrum arboreum (L.) DC.
Panicum clandestinum L.
Panicum dichotomiflorum Michx.
Panicum polyanthes Schultes
Parthenocissus quinquefolia (L.) Planch.
Phytolacca americana L.
Pinus virginiana P. Mill.
Plantago rugelii Decne.
Platanus occidentalis L.
Polygonatum biflorum (Walt.) Ell.
Polystichum acrostichoides (Michx.) Schott
Potentilla canadensis L.
Potentilla simplex Michx.
Prunus serotina Ehrh.
Quercus velutina Lam.
Ranunculus abortivus L.
Ranunculus recurvatus Poir.

Rhus copallina L.
Rhus glabra L.
Robinia pseudoacacia L.
Rubus allegheniensis Porter
Rubus flagellaris Willd.
Rubus occidentalis L.
Sambucus canadensis L.
Solidago nemoralis Aiton
Thelypteris noveboracensis (L.) Nieuwl.
Sanicula canadensis L.
Sassafras albidum (Nutt.) Nees
Scirpus cyperinus (L.) Kunth
Senecio anonymus Wood
Smilacina racemosa (L.) Desf.
Smilax glauca Walt.
Smilax rotundifolia L.
Toxicodendron radicans (L.) Kuntze
Vitis aestivalis Michx.

Appendix II

Peripheral Taxa of Five Surface Mines in Eastern Kentucky

Exotic Taxa
Achillea millefolium L
Ailanthus altissima (Mill.) Swingle
Allium vineale L.
Alnus glutinosa (L.) Gaertn.
Bromus japonicus Thunb..
Cerastium viscosum L.
Cerastium vulgatum L.
Chenopodium album L.
Chrysanthemum leucanthemum L.
Commelina communis L.
Coronilla varia L.
Elaeagnus umbellata Thunb.
Holcus lanatus L.
Lactuca serriola L.
Lespedeza bicolor Turcz.
Lespedeza striata (Thunb.) Hook. & Arnott
Lonicera japonica Thunb.
Medicago lupulina L.
Melilotus officinalis (L.) Pallas
Microstegium vimineum (Trin.) A. Camas
Phleum pratense L.
Poa compressa L.
Polygonum caespitosum Blume
Polygonum persicaria L.
Rumex acetosella L.
Rumex obtusifolius L.
Setaria faberi Herrm.
Stellaria media (L.) Villars
Trifolium campestre Schreber
Trifolium hybridum L.
Trifolium pratense L.
Trifolium repens L.
Tussilago farfara L.
Veronica officinalis L.

Native Taxa
Acalypha rhomboidea Raf.
Acer negundo L.
Acer saccharum Marshall
Aesculus flava Aiton
Agrimonia parviflora Aiton
Ambrosia trifida L.
Amphicarpaea bracteata (L.) Fern.
Anemone virginiana L.
Anemonella thalictroides (L.) Spach.
Antennaria plantaginifolia (L.) Richards.
Apocynum cannabinum L.
Aralia racemosa L.
Arisaema triphyllum (L.) Schott
Aristida dichotoma Michx.
Asarum canadense L.
Asclepias syriaca L.
Aster cordifolius L.
Aster divaricatus L.
Aster dumosus L.
Aster lateriflorus (L.) Britton
Aster undulatus L.
Betula lenta L.
Botrychium dissectum Spreng.
Botrychium virginianum (L.) Sw.
Cacalia atriplicifolia L.
Campanula divaricata Michx.
Cardamine concatenata (Michx.) Schwartz
Carex blanda Dewey
Carex frankii Kunth

Carex laxiflora Lam.
Carex lurida Wahlenb.
Carex purpurifera Mack.
Carex tribuloides Wahlenb.
Carya glabra (P. Mill.) Sweet
Carya ovata (P. Mill.) K. Koch
Caulophyllum thalictroides (L.) Michx.
Cercis canadensis L.
Chimaphila maculata (L.) Pursh
Circaea lutetiana L. var. *canadensis* L.
Cirsium discolor (Muhl.) Spreng.
Conyza canadensis (L.) Cronq.
Cuscuta pentagona Engelm.
Cyperus strigosus L.
Danthonia compressa Aust.
Desmodium glabellum (Michx.) DC.
Dioscorea villosa L.
Diospyros virginiana L.
Dryopteris marginalis (L.) Gray
Elymus virginicus L.
Erechtites hieracifolia (L.) Raf.
Erigeron philadelphicus L.
Erigeron strigosus Muhl.
Eupatorium rotundifolium L.
Eupatorium rugosum Houtt.
Euphorbia corollata L.
Euphorbia maculata L.
Fagus grandifolia Ehrh.
Fragaria virginiana Duchesne
Fraxinus americana L.
Geranium carolinianum L.
Geranium maculatum L.
Geum canadense Jacq.
Gnaphalium obtusifolium L.
Goodyera pubescens (Willd.) R. Br.
Hedyotis caerulea (L.) Hook.
Helianthus microcephalus Torr. & Gray
Helianthus tuberosus L.
Heuchera americana L.
Hieracium paniculatum L.
Hieracium venosum L.
Hydrangea arborescens L.
Hypericum mutilum L.
Hypericum stragulum Adams & Robson
Impatiens capensis Meerb.
Impatiens pallida Nutt.
Ipomoea pandurata (L.) G.F.W. Mey.
Juglans nigra L.
Juncus acuminatus Michx.
Krigia biflora (Walt.) Blake
Lactuca floridana (L.) Gaertn.
Lepidium virginicum L.
Lespedeza hirta (L.) Hornem.
Lespedeza intermedia (S. Wats.) Britton
Linum striatum Walt.
Linum virginianum L.
Liquidambar styraciflua L.
Ludwigia alternifolia L.
Luzula multiflora (Retz.) Lejeune
Lycopus virginicus L.
Lygodium palmatum (Bernh.) Sw.
Lysimachia tonsa (Wood) Kunth
Magnolia acuminata L.
Monarda clinopodia L.
Monarda fistulosa L.
Oenothera biennis L.
Osmorhiza claytonii (Michx.) Clarke
Osmunda cinnamomea L.
Oxalis grandis Small
Panicum boscii Poir.
Panicum capillare L.
Panicum commutatum Schultes
Panicum dichotomum L.
Panicum lanuginosum Ell.
Panicum laxiflorum Lam.
Panicum virgatum L.
Paronychia canadensis (L.) Wood
Pinus echinata P. Mill.
Pinus taeda L.
Plantago virginica L.
Poa alsodes A. Gray
Poa cuspidata Nutt.
Podophyllum peltatum L.
Polygonum pensylvanicum L.
Polygonum punctatum Ell.
Polygonum sagittatum L.
Polygonum scandens L.
Populus deltoides Bartr.
Populus grandidentata Michx.
Pyrrhopappus carolinianus (Walt.) DC.
Quercus alba L.
Quercus prinus L.

Quercus rubra L.
Ranunculus hispidus Michx.
Rhynchospora capitellata (Michx.) Vahl.
Rudbeckia hirta L.
Salix nigra Marsh.
Salix sericea Marsh.
Sanguinaria canadensis L.
Scutellaria elliptica Muhl.
Sedum ternatum Michx.
Silene virginica L.
Sisyrinchium angustifolium P. Mill.
Solanum carolinense L.
Solidago arguta Aiton
Solidago caesia L.
Solidago canadensis L.
Solidago erecta Pursh
Solidago flexicaulis L.
Solidago gigantea Aiton
Solidago rugosa Aiton
Sphenopholis obtusata (Michx.) Scribn.
Spiraea tomentosa L.
Stachys cordata Riddell
Stellaria pubera Michx.
Thelypteris hexagonoptera (Michx.) Weatherby
Tilia americana L.
Tradescantia subaspera Ker-Gawl
Trillium grandiflorum (Michx.) Salisb.
Triodanis perfoliata (L.) Nieuwl.
Typha latifolia L.
Ulmus rubra Muhl.
Uvularia grandiflora J. E. Smith
Vaccinium pallidum Aiton
Verbena urticifolia L.
Vernonia gigantea (Walt.) Trel.
Vicia caroliniana Walt.
Viola canadensis L.
Viola palmata L.
Viola pubescens Aiton
Viola sororia Willd.
Vulpia octoflora (Walt.) Rydb.