ALTERNATIVE PERFORMANCE STANDARDS FOR SPECIES DIVERSITY: A CONSIDERATION OF ECOLOGICAL AND TEMPORAL REALITY[1]

D. L. Buckner[2]

Abstract: The goal of returning diverse life to lands surface-mined for coal has followed the passage of the Surface Mine Control and Reclamation Act of 1977 (SMCRA) into State mining reclamation acts and regulations promulgated therefrom. Expectations for the level of plant species diversity that should exist on lands revegetated under SMCRA has taken the form of a variety of performance standards that reflect the prevailing attitude that species diversity is an attribute that can be "made to happen." Over 25 years of monitoring data from revegetated lands suggest that species diversity is not "made to happen" but rather "allowed to happen." For sites with at least moderately favorable soils and climate, a recurring conclusion based on long-term monitoring data is that grasses (typically abundantly represented in revegetation seed mixes) are highly competitive in post-mining conditions. SMCRA and similar state requirements for unbroken post-mining surface configuration covered by substantial depths of agriculturally suitable soil have provided the ideal environment for the wide-spreading and dense root systems that grasses possess. As a result, the occurrence of non-grass plant species has typically been limited. It is posited that the long-term status of plant species diversity will be related to occasional interruptions of the overwhelming ecological dominance that grasses most often presently hold. As a consequence, the accretion of plant species richness at any particular location will be slow and to some degree unpredictable. Given, thus, that species diversity after 10 years or even 20 years may still be competitively suppressed, quantitative approaches are set forth for "looking into the future" to evaluate the <u>availability</u> of the less-competitive plant species to respond to <u>eventual</u> opportunities that would allow them to proliferate in the revegetated plant communities. Central to these approaches is the need to avoid direct matching of species' abundance between reclaimed and reference areas. Instead, alternatives in the form of species presence, life-form similarity, and scale-corrected species density evaluations are described. Ecological reasoning underlying the approaches is examined.

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[2]David L. Buckner, Ph.D. Senior Plant Ecologist, ESCO Associates Inc., P.O. Box 18775, Boulder, CO 80308 (303 499 4277) e-mail: **escassoc@mindspring.com**

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Introduction

After the U.S. Congress in 1977 passed the Surface Mine Control and Reclamation Act (SMCRA), the wording of subsequent regulations included requirement that reestablished vegetation shall be "diverse, effective and permanent." Although federal regulation has relatively little to say about diversity beyond that, the state laws that have taken primacy in most western states for the most part do address species diversity as a separate performance standard.

Full scale revegetation with attention to adequate cover, forage production, woody plant density, and species diversity was something that seemed feasible at the inception of laws, regulations and guidelines addressing revegetation, even though it had never really been accomplished altogether. But perhaps with the optimism of the enthusiastic gardener there seemed no reason that it could not be *made to happen*. With over 25 years of "trials" accomplished, and with substantial amounts of monitoring data in documentation, there emerges a strong suggestion that long-term species diversity is not "made to happen" but rather "allowed to happen." The distinction is one underlying an important separation between a paradigm of controlled (and rapid) outcome (the "gardening" metaphor) and one of directed but weakly controlled outcome that may proceed at any of several, usually longer-term time scales (the "ecology" metaphor).

Post Mining Topography, Suitable Soils, and Grasses

Pursuant to the perceived need to prevent the "abuses of Appalachia" in western surface mine progression, the requirements of SMCRA and approved state programs included the replacement of evenly connected and generally moderate post-mining slopes covered with uniform depths of salvaged soil that met suitability criteria based on agricultural requirements. Given the special adaptation of grasses to occupy fine-textured material with their shallow but extremely dense and highly competitive root systems, the smooth topography and uniform presence of agriculturally suitable soils on reclaimed areas provides an extremely favorable set of circumstances for grasses. So favorable in fact that other life-forms in particular shrubs and perennial forbs are unable to compete. Most seed mixes for reclaimed areas have included a desired spectrum of life-forms and species, designed (hopefully) to produce a plant community with a prescribed diversity of species. However, the disproportionate suitability of post-mining landscapes to grasses leaves other life-forms with little chance of survival in the face of the extremely effective competition mounted by grasses. After an immediate short-term presence by forbs and shrubs of the seed mix, the dominance of grasses often excludes non-grasses.

The Ecological Entree of Non-grasses into the Plant Community

For sites with at least moderately favorable soils, and suitable climate (> 30 cm annual precipitation) long-term monitoring data have documented the excluding nature of the competition that grasses mount. It is speculated here that the long-term status of plant species diversity will be related to occasional interruptions of the overwhelming ecological dominance that grasses most often presently hold. Such interruptions may take the form of extended droughts, overgrazing, or other grass-inhibiting phenomena. Inasmuch as these stresses are erratic in occurrence, the accretion of plant species diversity at any particular site will be slow and unpredictable.

Since the status of plant species diversity after 10 years or even 20 years or more may still be competitively suppressed, the following quantitative approaches are set forth for the purpose of “looking into the future” to evaluate the availability of less competitive plant species to respond to eventual opportunities that would allow them to proliferate in the reconstructed plant communities. Central to these approaches is the need to avoid direct matching of species’ abundance between reclaimed and reference areas. Instead, alternatives in the form of species presence, life-form similarity and scale-corrected species density evaluations are proposed.

Species Diversity in Post-Mining Landscapes

In pursuit of means to evaluate evidence of the potential of a site to eventually possess plant diversity comparable to the un-mined areas, I believe that the appropriate goal is to determine whether the subject reclaimed plant community seems to have “all the parts present” or not. It is clear that the situation where the reclaimed plant community is completely dominated by a few species, to the exclusion of all others would constitute a failure as far as plant species diversity. But there is a much more common situation in which grass competition has and will continue for an unknown period to suppress the spread of other species, but those other species are present, albeit in small amounts and low sampling frequencies. This is the situation that demands closer scrutiny. It should be realized that in most western U.S. grassland, shrub-grassland steppe, and open woodland communities, where grasses dominate, the presence of forbs and subshrubs usually comprises a small amount of plant cover, often in the range 1 to 3 (5)%. The presence of these life forms in amounts greater than this tends strongly to indicate the past occurrence of some serious stress, such as overgrazing, that broke the competitive hold that grasses (and grass-likes) once held. This reality has been long acknowledged in the ecological literature and in range science.

Many coal operation permits contain species diversity requirements in the form of “x species of native perennial cool season grass with at least y % relative cover, w species of native perennial forb species with at least z % relative cover, etc.” These recipes were usually developed from baseline data, and the low percents for forbs or subshrubs present in the baseline communities gave the impression that these would be reasonably achievable goals. What was not appreciated then was that the legally mandated configuration of post-mining soils and topography would significantly favor the vigorous growth of grasses and that this would in turn significantly limit the rate at which non-grass species could establish a permanent presence. In most cases for twenty years and more, coal reclamation has used diverse seed mixes (wishfully) pointed toward the goal of reestablishment of a balance of grasses, forbs, subshrubs, and even trees on some sites. The most frequently observed result of seeding the diverse seed mixes is that, to highly varying degrees, initial plantings do show the presence of an encouragingly large fraction of the seed mix species. But as grasses firmly establish during the first three to five years, the non-grass species begin to fade, and although many sites have at least some of the non-grass species diversity left from seeding by time of potential bond release, many do not. This is not to say sites that have lost representation of the non-grass component of the original seed mix do not have diversity, because the presence of volunteer individuals of native forbs and subshrubs, as well as native perennial grasses and even trees and shrubs, is a commonly observed occurrence in the more mature reclaimed plant communities. These volunteers often seem to have come from propagules present in the soils, and hence are more common at mines where direct placement of topsoil after salvage (i.e. direct-haul topsoiling) is practiced. They also may have arrived by wind or animal movement. But in nearly all cases, their presence is quantitatively small.

Thus the reclaimed area plant community at the time of bond release testing, even though at least nine years old, is arguably still immature. Although the ten-year liability period was intended to address the issue of "permanence," it is clear now after nearly thirty years' observation of reclamation results that the process that would lead to full quantitative restoration of plant species diversity will typically take longer, and in fact will depend on the unpredictable occurrence of stresses such as drought or overgrazing that reduce the competitive strength of grasses. The task of evaluating the adequacy of a reclamation area from the standpoint of species diversity then must center on determining whether an adequate assemblage of non-grass species is present (without regard to quantitative abundance) in anticipation of eventual stress-induced opportunities to make an expanded presence in and among the dominant grass cover.

Species Diversity Evaluation Tests

With the above-discussed need in mind, the following tests of species diversity are proposed for western U.S. sites that have restored species diversity as a performance goal. Species diversity suitable to support approved post-mining land uses (these would usually be rangeland and wildlife habitat) may be judged using the following three tests; success would be demonstrated by passing at least two of the three. These tests are numerical, but rather than using measures of abundance, they use a measure that may be referred to as "species density." This measure is expressed as number of species per 100 square meters and is based on species presence data easily collected in conjunction with cover or shrub density sampling. Since many field data collection techniques used on coal sites are based on 50 meter transects, the additional notation of the presence of all species one meter to either side of the transect after completing, for example, cover sampling is minor addition. This has been a routine part of ESCO field sampling technique in conjunction with point-intercept data collection for many years.

The advantage of species density measures is that they reflect presence without regard to abundance, hence reducing the age difference between young (reclamation) plant communities and much older un-mined plant communities.

Alternative Test A): Total Species Density Test

It is proposed that this overall reclamation diversity standard be judged based on the species density values observed along with cover sampling in 100 sq.m. sample plots. It is further proposed that the species density numbers be subjected to sample adequacy assessment in the usual manner.

For purpose of establishing the range of species density within the reference areas, the 75% range of variation would be established as:

$$z \times s \qquad (1)$$

Where:

z = the number of standard deviations (both ways from the mean) encompassing 75% of the normal distribution (= 1.15; see Rohlf and Sokal 1969, Table P)

s = standard deviation (n-1) of species density data from the reference area

The standard would be the point on the lower tail at which the central 75% of the distribution of overall species density in the reference areas begins. Mathematically this would be:

Mean reference area species density (no. of species per 100 sq.m.) - 1.15 s (2)

Note that this test addresses total species density, not just native species density (see C) below). Noxious weeds are omitted. The point of addressing total species density, including annual/biennial species and introduced species (but not noxious weeds), is that the total species density is arguably a strong indication of the existence of niche spaces that could eventually be occupied by the native forb and woody plant species typical of the pre-mining plant communities.

The final step for this assessment will be comparison of the mean total species density of the reclaimed area to the reference area-derived standard number (above). If the reclaimed area mean exceeds the standard, the Test A is passed. If the reclaimed area mean is less than the standard, a hypothesis test will be undertaken. This would be accomplished using the expression set forth above for a one-sample t-test (using the tradition null hypothesis and traditional test criteria) comparing the reclaimed area species density mean.

Alternative Test B): Assessment of the Distribution of Species Density Among Lifeforms in Comparison to the Reference Areas

This test relates to the distribution of the presence of species among the various lifeforms in comparison to the reference areas. This standard will use the Motyka similarity index to assess the resemblance of the distribution of species density by lifeform of the reclamation vegetation to that of the reference areas. The standard for such a comparison would relate to the average internal resemblance (i.e. between-sample similarity) of applicable reference area(s) for species density data.

The Motyka similarity index would be used as follows:

$IS_{mo} = 2c / (a + b)$

Where:

c = the smaller of the paired species density values (for each lifeform) of the reclaimed and reference areas

a = total of species density values for lifeforms of the reclaimed areas

b = total of species density values for the lifeforms of the reference area*

Only species density by vascular plants would be included. Life-forms to be used will include:

Annual/biennial forbs

Annual grasses

Perennial forbs

Perennial cool season grasses

Woody plants are not included here because they are typically addressed separately under their own performance standard(s).

Alternative Test C): Assessment of the Presence of Native Species

The third alternative assessment of the species diversity of reclaimed lands makes direct reference to the presence of native western North American plant species in reclaimed areas.

Total cumulative # of native species* $\geq$ avg. reference area native species density (# species / 100 sq.m.)

*in the adequate species density sample of the reclaimed area and including alfalfa and / or cicer milkvetch which have often been included in seed mixes as nitrogen –fixers in light of the lack of suitable and available native nitrogen-fixers.

Two other notes need to be made about the above test alternatives:

1) Where there is reference to an adequate sample of species density, many reading this would fear another sample adequacy goal. The experience of over 15 years with this measure is that sample adequacy for species density (on the species per 100 sq.m. basis) is achieved at or below the sample size that adequacy of cover sampling is achieved. And for those unfamiliar with acquiring an adequate cover sample, when using a broad-based sample such as the 50 meter/ 100 point method used by ESCO and other consultants, adequacy (alpha = 0.1, d = 0.1) is usually achieved with twenty samples, frequently the minimum size allowed by regulation / guideline. Hence, if collection of species density data accompanies collection of cover data (as it logically and practically does), there is no significant additional sampling burden.

2) For alternative test C, it is important to understand that the cumulative species number in the adequate species density sample (i.e. the cumulative no. of species in the approximately 20, or fewer, reclamation area 100 sq.m. samples) is compared to the average species density (no. per 100 sq.m.) of the reference area. Hence, the average number of species per 100 sq.m. in the "mature" vegetation (reference area) is compared to the accumulation of species in an area of reclamation perhaps 20x greater in size. The point of this is that if the species are really there, in a slightly scaled up (20x) view, then the chances are arguably good that given time and episodes of opportunity, they have a reasonable likelihood of filling in to reference area-like densities eventually. Note that we are not talking about the cumulative species presence in, for example, a whole bond release block, which might be of the order of 1000x to 10,000x larger than the 100 sq.m. reference area basis of comparison. It is thought that projection of fill-in on that scale would approach credulity.

Application of the Proposed Tests

The above-proposed tests of successful reestablishment of species diversity are all related to the levels of species diversity of the un-mined areas. They are not technical standards. They were developed from an accumulated understanding of the dynamics of both reclaimed and reference area plant communities at several coal mines is the western U.S. The tests have themselves been tested for mines in northeast Wyoming, southeast Montana, and northwest Colorado on sites for which many years' detailed monitoring data exist. The tests to date have resulted a few "fails" but mostly "passes." This has been encouraging, in light of the fact that I think each of the three tests have logical underpinnings and directly relate evidence of likely eventual species / life-form diversity of reclaimed areas to the plant diversity of the vegetation "native" to the site. That so many reclamation areas pass these tests is a very positive testament to the success of SMCRA intentions.

Literature Cited

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