A Comparison of Surface Vegetation on Unreclaimed 1949 Indiana Coal Spoilbanks in 1964 and 1981

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Introduction

In 1964, Munsee (9) studied the ecology of ants on relatively barren unreclaimed Indiana spoil banks originally deposited in 1949-51. In 1981, Schrock (12) repeated the methodology at the same 21 sites, now mostly revegetated. While the primary focus of both studies was the surface active insect populations (10), samplings of both the soil (14) and vegetation at each site were used in analyses to explain the distribution of selected insects. Of these major factors studied by Munsee and Schrock—soils, herbaceous vegetation, trees, and insects—this paper summarizes the surface vegetation data.

Previous studies (1, 11, 17) studying successional changes at one point in time by comparing a series of multi-aged spoil banks assume a uniformity of both spoils and microclimate, but themselves often reveal adjacent but highly contrasting sites of equal mining age.

The Munsee and Schrock studies, 17-years apart, constitute one of the few real-time comparisons of changes on humid Midwestern spoil banks over a substantial period of time, and on which a large amount of data has been amassed (9, 10, 12, 13, 14, 15).

Methods

In 1964, Munsee selected an ecological study area in the old Sunspot Mines, strip-mines south of Centenary in Vermillion County, Indiana, in Township 14N, Section 24 (10). Physical site descriptions are detailed in Schrock & Munsee (14). The spoilbanks resulted from surface coal mining by Ayrshire Colleries from 1949 to 1951. Ayrshire sold about 300 acres of the spoilbanks to the Clinton Chapter of the Isaac Walton League. Protection provided by the League and the remoteness of the research site prevented disturbance of the research site over the past 41 years. All seed dispersal is presumed natural.

Twenty-one research sites, 19 on mined spoilbanks and two in adjacent unmined area, were selected in 1964 to provide an assortment of exposures and slopes (9, 14). The size and shape of plots varied with topography (Figure 1). Plots were oriented to avoid problematic areas. A variety of tops, slopes and bases of ridges were sampled. Detailed 1964 field notes and the rough and varied terrain permitted reestablishment of the same plots in 1981.

Sites were designated by letters, beginning with "Site A" in the south end of the area and working north along the mined ridges and west to east when sites cut across ridges. "Site A" was an unmined but previously cultivated site; "Site W" was an unmined wooded site south of the mined area. Therefore, tabular data are presented in the order "W, A, B, C, D. . .T."

Because of the wide variety of plant forms on the sites and due to the rugged terrain, Munsee chose a modified point-contact method to describe the plant community,

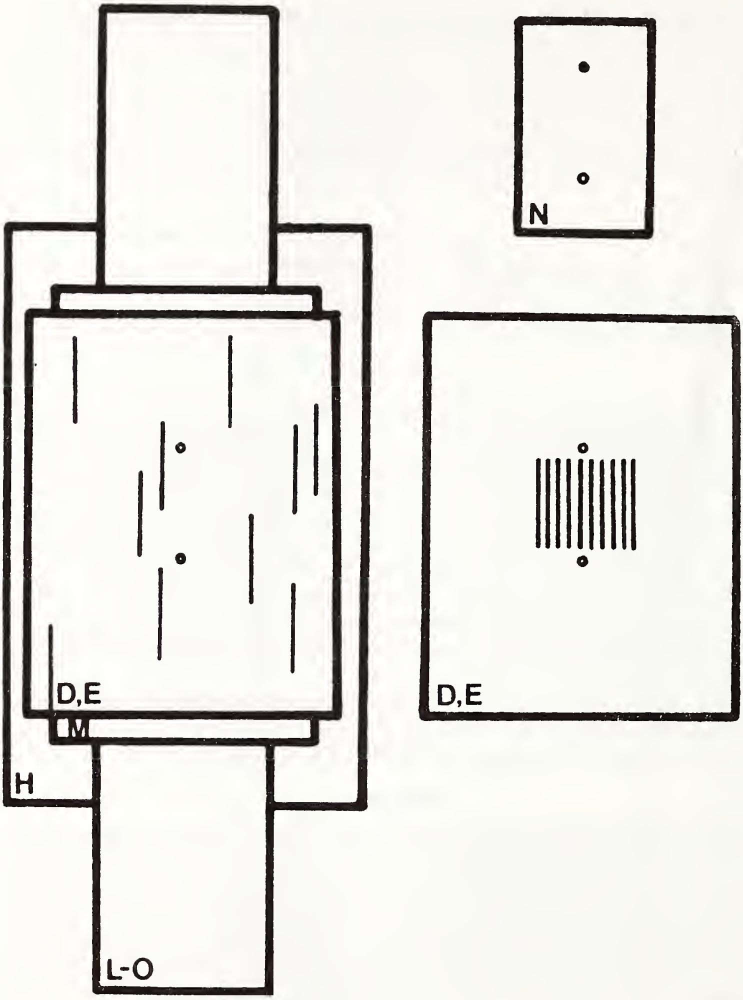

FIGURE 1. Variation in size of vegetation plots. The change in the point-contact sampling pattern is represented by the ten random lines (D, E left) used in 1964 and the central grid of ten lines spaced 30.5 cm apart in 1981 (D, E right).

and this method was also used in 1981. However, while most procedures were the same, there were some differences in the sampling pattern and in the equipment used in these two studies.

Working alone on the barren spoils in 1964, Munsee needed a point-frame that could be set up and operated by one man. He used two 1.8 meter (six foot) 1.6 cm (5/8″)-diameter metal rods to establish the ends of the point frame. A metal cross-bar was welded one foot from the sharpened bottom end. This permitted the rod to be easily driven into the ground and guaranteed the top would extend to a standard height. Ringstand clamps fitted with thumbscrews were fastened to the top end of the rods. This anchored the ends of a clothesline that spanned the 3.27 meter (10′ 9″) between the rods. The rods were reinforced with guy wires and the clamps were adjusted so the line was taut.

Stretched between the rods, the line was divided by ten marks at 30.48 cm. (one foot) intervals. At each of these points, Munsee fastened a plastic draw-drape pulley. A 28 gram (five ounce) carpenter's plumb was attached to nylon fish line and suspended from each consecutive pulley to define the line of point-contact. At each site in 1964 and again in 1981, the plumb line was dropped ten times along each of ten lines for a total of 100 plumb line drops.

In use, the plumb line was lowered slowly from each consecutive pulley. Tallies were made as follows:

1. One tally was made each time the point of the plumb touched a live plant part. Since heavy herbaceous cover resulted in many hits per descent, there was no limit to this tally.
2. Litter was considered any dead and prostrate plant material contacted by the point of the plumb as it reached ground level and therefore there was a limit of 100.
3. Dead parts of live plants and live plants were tallied by plant and not as litter.
4. Bareground was counted when the ground surface contacted by the plumb was stone, clay or any other inorganic material. Again 100 was the limit.

These tally procedures were used uniformly in 1964 and 1981.

The frame apparatus in 1981 was built with different materials. Instead of metal rods and a clothesline, the frame was constructed of wooden boards as shown on site E in Figure 2. The height of the poles and the spacing of the points along the "line" board were identical to the 1964 dimensions. Notches rather than pulleys defined the lowering of the plumb line. This frame required two persons to move but otherwise was much more rapidly set up. The change in frame design is presumed to make no difference in tally results.

FIGURE 2. View facing east at research site E in 1981. The wooden plant frame is in place over heavy growth of *Melilotus*.

In 1964, the frame was set up ten times at each research site, the position of ten "plots" at each site was determined by a random numbers table. Since many of the mined sites were sparsely vegetated, this method sampled from a wide area around the pitfalls. In 1981, all but D site were well vegetated. In addition, the 1964 "random plots" could not be located again. Since vegetation on the sites was heterogeneous and clumped, two random samples even at the same point in time would show different results. Since replication was impossible, the 1981 vegetation "plots" were set in a 3.048 meter (10-foot) square grid centered on the pitfall traps. This difference in sampling is illustrated in Figure 1.

It is realized that this compact grid decreases the chances of encountering plants sparsely distributed at the site. Bushy or clumped plants in the 1981 grid are likely to be intercepted by several of the lines spaced only 30.5 cm. (one foot) apart. However, two benefits are gained: 1) in denser vegetation, it is likely that the vegetation within 1 to 3 meters will influence the ant sample more than the plants chosen randomly 10 or more meters away, and 2) since the trapsites are relocatable, this vegetation survey can also be repeated in any future follow-up to this study. In addition, this plant survey was originally designed as and remains an examination of factors influencing insect populations on stripmines.

In 1964, Munsee identified common plants in the field. Difficult material was collected and identified in the laboratory. When plants were in the seedling stage, their identity was determined by referring to nearby plants believed to be of the same genus or species. Where possible, identical plants were collected off-site and placed in a plant press. When dried and identified, these were mounted on herbarium paper and labelled. Voucher specimens of both herbaceous specimens and tree leaves were placed in the Indiana State University Herbarium. Munsee's voucher specimens were examined prior to field work in 1981. Specimens collected in 1981 were also dried, mounted, labelled, and deposited in the I.S.U. Herbarium.

Sweet clover, very common in both 1964 and 1981, could be identified to species (i.e., *Melilotus alba* Desr. and *M. officianalis* (L)Lam.) when flowering. Many plots contained a mixture of the two species and since many non-flowering stems were intermixed, only the genus was tallied.

The 1964 plant tallies were conducted over many weeks between servicing of the pitfall traps. Considering that vegetation was sparse, this probably produced little disturbance to both the vegetation and the insect samples. By 1981, the vegetation was dense enough that the process of tallying plants would trample much of the vegetation and distort the insect samples. Therefore, plant tallies were conducted during the last two weeks of the study to minimize this disturbance. Since there is a gradual change throughout the seasons, this variation in tally date, plus overall variation in weather between the two years, should be borne in mind when interpreting the results.

Munsee based his determinations on the revision of Gray's manual by Fernald (6) and on Deam's *Grasses of Indiana* (5). Schrock's determinations were mostly from Gleason and Cronquist (7) and with substantial help on difficult species from Ralph Brooks of the Kansas State Biological Survey.

At each site, the plant frame was set up ten times and using the modified point-contact system described above, this provided ten samples of the vegetation at each site. Frequency of a plant species was defined as the number of linear plots in which the species was encountered at least once, divided by ten. Therefore, if a plant was sparse but very bushy, it would be encountered only on one or two plots and have a low frequency although it might have a high number of point-contact hits due to its dense foliage.

In 1964, Munsee also calculated a relative frequency, a relative density, and a relative dominance for plants at each site and summed them for an importance value for each species (9). However, only the real counts and frequencies were used for the 1964-1981 comparisons for the following reasons:

1. The "plot size" was identical in 1981 and effectively so in 1964, reducing the need to convert to proportions to compensate for different sizes of sample areas.
2. Actual plant hits may directly reflect both biomass and sun-light interception and no longer reflect this when reduced to proportions.
3. The ecological value of an abstract "importance value" constructed from precisely one-third frequency, one-third density, and one-third relative dominance is difficult to show in spite of its use in forest community studies beginning with Curtis and McIntosh (3).

Because of shortcomings described by Chambers (2), standard diversity indices were not used in comparing the vegetation. To describe the complex patterns of similarity between sites, a cluster analysis was performed using each site as a case. For this task, BMDP statistical program P2M was used as modified to run on the Kansas University Computing Center Honeywell DPS-3/E.

Dendrograms were constructed to compare sites with the distance between two sets of vegetation data defined as the chi-square test of equality of the two sets of frequencies. The computer program begins by comparing each pair of cases and using this chi-square test, joins the closest two cases. When two cases are joined, a new centroid is formed by averaging each variable. In the next round of searching for the shortest distance, this centroid is compared with other candidates for membership to the next larger cluster. The number of cases (or pseudo-cases) is reduced by one at each step until all are clustered. The freely rotating cluster dendrograms are then ordered into a successional series by pulling unrecovered site D to one side and unmined forest site W to the opposite side.

Cluster analyses were performed for the 1964 and 1981 sites separately, and for all of these sites taken together. The methodology described above was applied to plant hits, plant frequencies, and plant occurrence. Plant occurrence was based on a data grid of ones and zeros reflecting whether the plant species occurred at the site or not.

Results

Percent bareground in 1981 is greatly reduced at all sites except site D (Figure 3). Ordered from 100% bareground to no bareground in 1964, only E, H, P, and F have

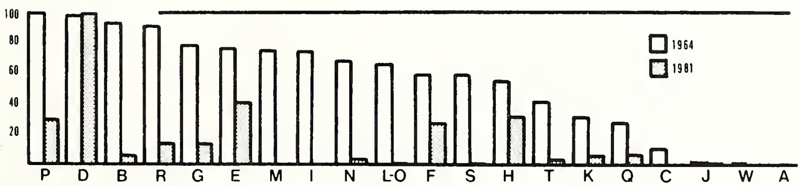

FIGURE 3. Changes in percent bareground at each of 20 research sites between 1964 and 1981.

substantial bare surfaces in 1981. Based on this same ordering system, 1981 sites have generally increased plant production as represented by hits using the modified point-contact system (Figure 4). The *Melilotus* fraction has increased on those sites with remaining bareground (E, H, P, and F) and at sites Q and N. In other cases, it is either reduced or absent. Slight decreases in plant hits occurred at R, A, and barren site D.

Table 1 shows that *Melilotus* dominated the 1964 sites along with *Aster*, mustard, and ragweed (*Ambrosia*) making a distant showing. By 1981 (Table 2), *Aster* and *Melilotus* are reduced, ragweed is nearly absent and goldenrod (*Solidago*), blackberry (*Rubus*), Queen Anne's lace (*Daucus carota*), and poison ivy (*Rhus radicans*) abound. Dogwood

TABLE 1. Bareground, litter and plant hits recorded for 20 research sites in 1964. Numbers represent interceptions of each species during a total of 100 plumb line drops. Ten drops were made along each of ten randomly determined lines at each site.

	W	A	B	C	D	E	F	G	H	I	J	K	L-O	M	N	P	Q	R	S	T
Bareground	2	1	93	11	98	77	60	78	56	75	3	33	66	75	68	100	29	91	60	42
Litter	89	96	13	89	—	33	59	23	49	31	97	70	58	29	44	—	72	18	63	59
Ambrosia sp.	—	3	14	17	—	7	5	—	—	9	43	1	78	—	1	—	34	—	12	15
Apocynum sp.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Aristida oligantha	—	—	11	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	6	—
Asclepias syriaca	—	—	—	6	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Aster spp.	—	—	—	1	—	31	1	1	2	6	—	4	4	1	—	—	—	3	4	11
Atrichum angustatum	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromus commutatus	—	—	—	7	—	—	—	—	20	—	—	—	7	—	—	—	—	—	—	—
Campsis radicans	—	—	—	—	—	—	—	—	121	—	—	—	—	—	—	—	—	—	—	—
Carex spp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Celastrus sp.	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chenopodium album	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—	—
Chenopodium sp.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Convolvulus sepium	—	—	—	—	—	—	—	—	—	—	—	31	4	—	—	—	5	—	1	—
Cornus spp.	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Danthonia spicata	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Daucus carota	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Desmodium sp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Echinochloa crusgalli	—	—	—	—	—	—	—	—	—	—	—	—	12	—	—	—	2	—	—	—
Eupatorium altissimum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Fraxinus sp.	2	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Ipomea pandurata	—	—	—	—	—	—	—	—	14	—	—	—	—	—	—	—	—	—	—	—

Lactuca spp.	—	2	—	—	—	1	—	—	—	10	—	—	1	1	—	—	1	—	1	3
Lepidium densiflorum		—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—
Lepidium sp.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Lespediza spp.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Melilotus spp.	—	—	12	36	—	69	70	33	36	95	52	43	58	53	39	—	66	55	66	84
Oenothera sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—
Panicum huachuacae	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Parthenocissus sp.	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Plantago lanceolata	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa compressa	—	—	—	5	—	—	—	—	4	—	15	—	24	—	—	—	—	—	—	—
Poa pratensis	—	42	—	27	—	—	—	—	—	1	—	—	—	—	3	—	—	—	—	—
Polygonum spp.	—	—	1	—	2	—	—	1	—	—	—	—	—	1	—	—	—	—	1	—
Potentilla sp.	—	1	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Rhus radicans	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rubus sp. (blackberry)	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rubus sp. (dewberry)	—	8	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Rumex sp.	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sambucus sp.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Solanum carolinense	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Solidago spp.	—	—	—	35	—	—	—	—	—	—	—	1	13	1	2	—	—	—	—	3
Stellaria sp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tragopogon sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Trioda flava	—	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Ulmus americana	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Verbena urticifolia	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitis yulpina	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Plant Hits:	22	88	38	140	2	108	87	35	209	123	113	83	202	57	45	0	120	58	97	117

TABLE 2. Bareground, litter and plant hits recorded for 20 research sites in 1981. Numbers represent interceptions of each species during a total of 100 plumb line drops. Ten drops were made along each of ten lines centered in each site.

	W	A	B	C	D	E	F	G	H	I	J	K	L-O	M	N	P	Q	R	S	T
Bareground	—	—	5	—	100	41	29	14	33	—	1	7	1	1	4	29	1	14	1	3
Litter	100	100	95	100	—	59	71	86	67	100	99	93	99	99	96	71	99	86	99	97
Puffball	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Lichen sp. A	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Moss sp. A.	—	—	—	—	—	2	1	3	—	4	—	10	—	3	10	28	19	2	28	12
Maidenhair Fern	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Ebony Spleenwort	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acer negundo	—	—	—	3	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	2
Acer saccharinum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Ambrosia sp.	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3	—
Apocynum sp.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—
Aster spp.	—	—	1	—	—	—	—	—	—	109	8	41	—	1	—	—	—	—	—	7
Brassica sp.	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—
Campsis radicans	—	—	—	—	—	—	—	—	102	—	—	—	—	—	—	—	—	—	—	—
Carya spp.	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cirsium altissimum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Cirsium vulgare	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Cercis canadensis	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornus spp.	33	—	—	54	—	—	1	—	—	—	2	3	1	—	—	—	11	—	—	—
Crataegus spp.	—	1	—	—	—	3	—	1	—	—	1	3	—	1	—	—	6	—	—	10
Daucus carota	—	—	5	—	—	1	2	1	—	—	15	38	—	35	10	26	39	2	26	1
Diospyros sp.	—	—	3	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Elymis virginicus	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	4	—	—	—	—
Eupatorium altissimum	—	—	2	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Fraxinus sp.	—	2	—	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Geum canadense	—	—	1	—	—	2	—	—	1	1	5	5	—	8	10	—	5	1	—	1
Gleditsia triacanthos	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Graminae sp. A	—	—	48	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	8	4
Hierocium longipilum	—	—	1	—	—	—	—	—	—	—	—	2	—	—	4	—	7	—	3	—
Juglans nigra	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lactuca spp.	—	—	—	—	—	—	—	—	—	—	2	7	—	—	—	—	—	—	—	1
Lespedeza spp.	—	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lonicera sp.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Malus sp.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Melilotus spp.	—	—	2	—	—	110	63	50	93	71	13	13	1	3	45	6	126	3	53	1
Muhlenbergia sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Parthenocissus sp.	5	13	—	—	—	—	—	2	—	—	11	6	—	—	2	—	—	—	—	—
Poa compressa	—	9	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Poa pratensis	—	—	—	—	—	—	5	10	—	—	—	—	—	—	—	—	—	—	—	—
Pinus spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—	—	26	—	—
Polygonum spp.	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2	10	—	4	—
Potentilla sp.	—	— 2	—	—	—	—	—	—	—	—	—	—	2	2	—	3	1	—	—	2
Prunus serotina	1	—	—	12	—	—	—	—	8	13	—	4	2		—	—	—	1	—	—
Quercus spp.	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	5	—	—
Rhus radicans	—	77	18	132	—	2	4	26	10	—	73	19	198	34	—	—	4	1	—	54
Rosa multiflora	—	—	—	—	—	—	43	4	3	—	—	—	1	—	—	—	—	—	—	
Rubus sp. (blackberry)	—	—	9	3	—	43	12	3	6	34	8	—	—	16	3	—	17	3	11	22
Rubus sp. (dewberry)	—	—	21	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Sanicula marilandica	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Sassafras albidum	1	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Solanum carolinense	—	—	—	—	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Solidago spp.	—	—	16	31	—	3	3	2	—	3	2	—	52	2	10	4	24	—	2	—
Spartina sp.	—	—	—	—	—	—	22	1	1	—	—	—	—	—	2	—	—	—	—	—
Ulmus americana	—	1	—	4	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—
Ulmus rubra	8	—	—	—	—	—	—	4	—	—	4	1	—	—	—	—	—	—	—	—
Urtica sp.	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—
Veronia altissima	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viola spp.	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitis vulpina	—	1	—	7	—	—	—	—	—	—	2	8	—	—	2	—	—	—	—	5
Total Plant Hits	52	125	157	248	2	179	161	114	226	239	149	175	267	117	103	75	269	46	138	122

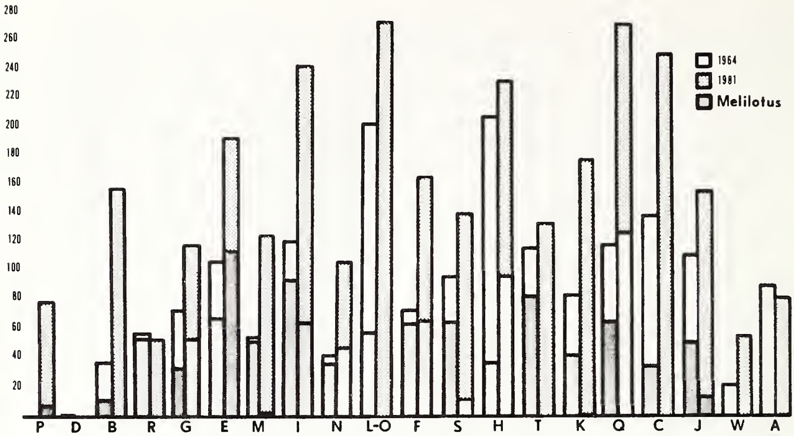

FIGURE 4. Total plant hits and *Melilotus* fraction sampled by modified point-contact system at 20 research sites in 1964 and 1981.

(*Cornus*), *Geum* and mosses are increasing in numbers and sites. Trumpet creeper (*Campsis radicans*) has failed to spread beyond its entrenchment site H. In 1964, only 8 sites scored over 100 plant hits, one site over 200. By 1981, sixteen sites exceeded 100 hits and five of these surpassed 200 in spite of early withering *Melilotus* (see discussion under plant methods).

The period from October 1, 1980 to March 31, 1981 was the driest six months in 100 years in Indiana, according to Meyer (8). Yucca plants near the stripmines were observed flowering three weeks earlier than usual. Such an early season and drought may have an impact on the plant sample. In 1964, Munsee noted in field notes that *Melilotus* was luxuriant and flowering in late June. In 1981, with the early spring, all but a few sheltered *Melilotus* finished flowering in mid-June and most were shriveled with withered leaves during the plant tallies. This could depress the apparent *Melilotus* count.

A decrease in herbaceous plants accompanies shading by trees. This results in the near-barren site D being clustered near forested sites W and A in 1964. In 1981, lack of plant hits excluded D from the clustering process. The larger number of plants and increase in species together produce a taller 'drawn out' dendrogram for 1981 (Figure 5).

When we build the dendrogram simply on whether each plant is present or absent at the site, D is clustered away from the forest with B and C (Figure 6, top). While plant hits overestimate bushy solitary plants and plant occurrence ignores plant abundance, plant frequency based on the percent of linear "plots" that intersect a plant at least once provide an intermediate picture (Figure 6, bottom). The fact that all of these approaches yield a site A clustered near site W indicates some congruence with biological reality since site A is unmined and reforesting. Occurrence and frequency dendrograms for 1981 (Figure 7) also have the long appearance from more plant species and generally higher numbers of hits. The lack of plants at site D in 1981 makes the orientation of the mined-site clusters, to the right, more subjective and many are left unordered due to a lack of criteria.

Most interesting are the 1964 and 1981 plant hit data clustered together (Figure 8). By 1981, only site H remained most like the 1964 association. 1981 site R, which visually appears most forest-like, is nearest the 1964 wooded site W. The vegetation of sites A and C, once similar to that of site W, are now more like the advanced stripmine sites.

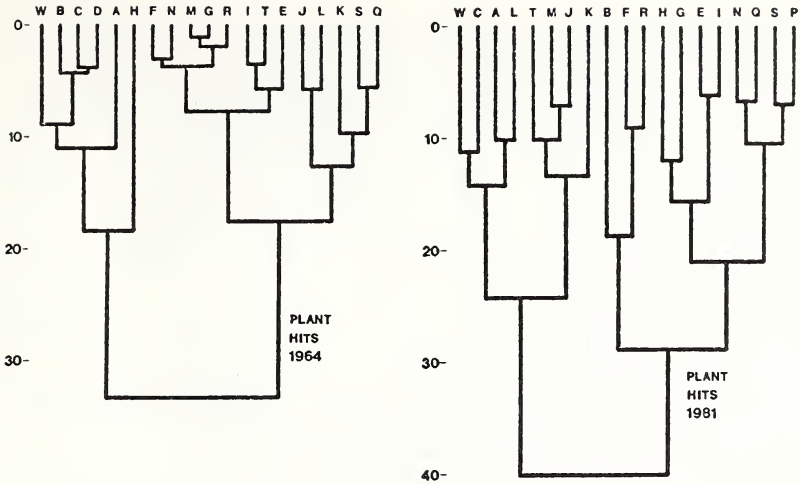

FIGURE 5. Dendrograms clustering sites on number of plant hits per species in 1964 and 1981. Successional stages would be read from right to left.

The mere presence and absence of plants, disregarding their numbers, shows much the same pattern (Figure 9). Site H again remains stagnant. The dichotomy between 1964 sites and 1981 sites is striking.

Discussion

Descriptions of revegetating stripmines are generally framed in terms of plant succession. Pre-settlement Indiana consisted of a mosiac of habitat types, defined by Daubenmire (4) as land areas capable of producing similar plant communities at climax. Fires, tornadoes, landslides, floods, insect infestations and other natural disasters permitted the growth of characteristic seral plant communities that eventually end at a climax com-

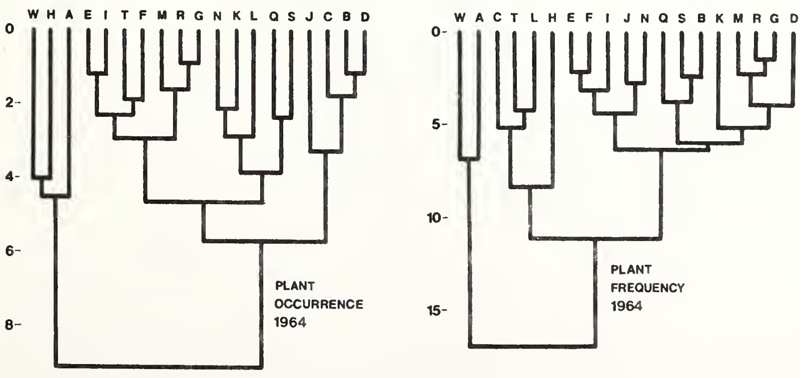

FIGURE 6. Dendrograms clustering 1964 sites on presence and absence of plants, and on plant frequency. Successional stages would be read from right to left.

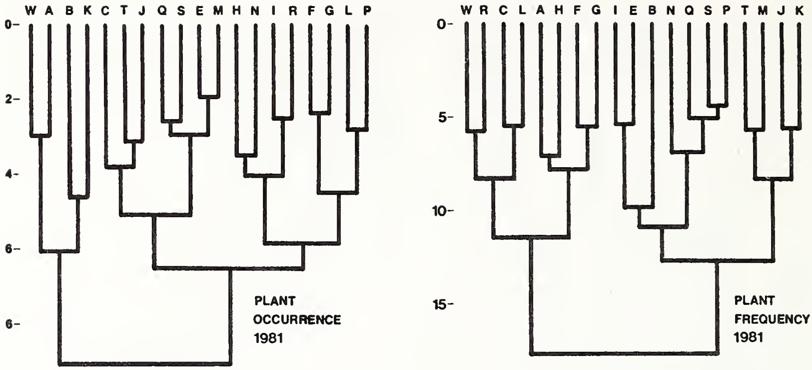

FIGURE 7. Dendrograms clustering 1981 sites on presence and absence of plants, and on plant frequency. Successional stages would be read from right to left.

munity. Additional disturbances by man make such seral communities more common. Where the soil layers are intact and a seed supply is available, succession occurs rapidly and is termed secondary succession. Where bedrock or regolith is exposed and no soil strata or seed supply are present, succession is termed primary, and thousands of years are required for the development of soil horizons. Stripmining that buries the topsoil and leaves a sterile subsoil-regolith mixture at the surface, is followed by an intermediate type of succession, undoubtedly much faster than primary but far slower than the return of a fallow farm field.

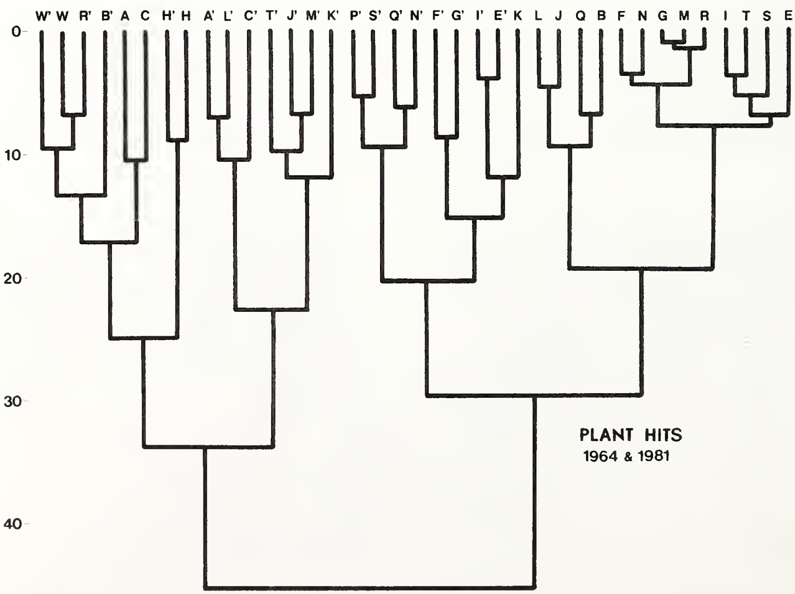

FIGURE 8. Dendrogram clustering all 1964 (W, A, B. . .T) and 1981 (W′, A′, B′ . . .T′) sites together on basis of plant hits.

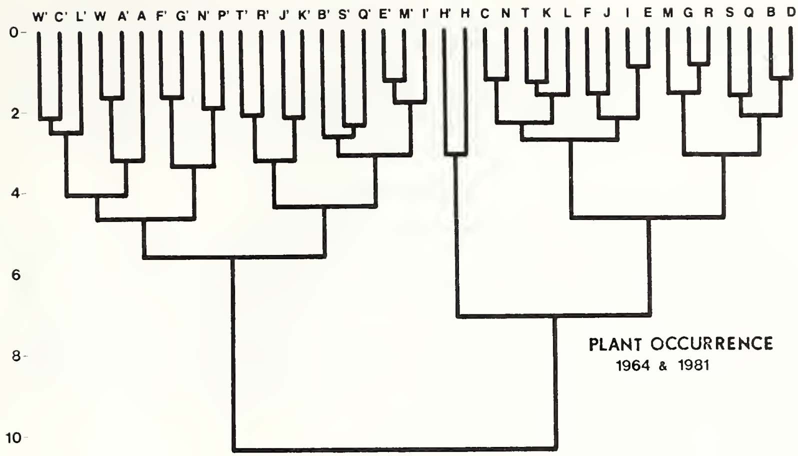

Figure 9. Dendrogram clustering all 1964 (W, A, B. . .T) and 1981 (W′, A′, B′. . .T′) sites together on basis of presence and absence of plants.

Spoilbanks are currently viewed as macrobiotically sterile, without significant seed banks, and totally inhospitable to most plant colonists for some time, as is shown here at site D. Some amount of time is therefore necessary for these spoils to pass a threshhold permitting some plant cover. The initial plants that invade these spoils await weathering of the spoils as is documented in this study. Significant site improvements provided by the plants themselves include the lowering of surface temperatures by shading the ground, the increasing organic matter as plant tissues accumulate, and the improved percolation of water through the soil due to root development.

The unreclaimed spoils are very rugged and present far more topographical and microclimatic variation than was originally present. These 1964 and 1981 studies are both embryonic stages in the exceedingly slowed development of these sites. At this time, environmental conditions are dissimilar enough that no one single climax community could be forecast. Redevelopment of plant communities and soil profiles roughly equivalent to pre-mining may never occur.

Summary

Bareground decreased and plant cover increased at all but one site as sampled by a point-contact method in 1981. Plant richness increased compared to 1964 and plant associations changed on many stripmine sites. Cluster analyses based on chi-square similarity were used to group similar sites on the basis of plant hits, plant frequencies, and plant occurrence. Arraying the clusters from still-barren sites to unmined sites suggests a tentative successional series. Sites array differently for herbaceous vegetation compared to arrays for physical factors, trees, or insects.

Plant succession is therefore used here in a descriptive sense, a counting and identifying of the organisms and a clustering of associations that occur serially on these spoilbanks. Once a threshhold, primarily measured here by pH, is exceeded, the sites vary widely in plant communities. It is possible that some will fail to converge eventually and, in the sense of Tansley (16), develop into a different edaphic climax on abnormal soil, a topographic climax due to aspect and microclimate, or topoedaphic climax due to both. The poison ivy of L-O, the pines of R, the willows of T, etc. should keep these

sites distinct for many decades. A sobering conclusion unavoidable from the data is that site D failed to revegetate and shows no moderation of physical features permitting revegetation in the near future. This 40-year-old barren spoilbank and the variation in the revegetation of the other spoilbanks of essentially the same age must be considered in studies that try to deduce successional changes by examining multi-aged sites at one point in time.

Acknowledgments

The Clinton Chapter of the Isaac Walton League granted permission for the 1964 and 1981 studies. Munsee designed the original 1964 study and carried out the 1964 fieldwork. Schrock conducted the 1981 fieldwork, the between year comparisons, and wrote this text. We would like to thank our wives who were financially supportive throughout the research period. We are indebted to Dr. Leland Chandler, Purdue University, and Dr. Edward Martinko, University of Kansas, who served as major professors in the respective studies, and to Ralph Brooks of the Kansas State Biological Survey who identified some of the 1981 specimens.

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