NUTRITIVE LEVELS IN PLANTS FROM STRIPMINED AREAS IN EASTERN OHIO[1]

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Abstract. Data on nutritive quality of vegetation for stripmined lands were obtained in 1972–73 from 2 Ohio counties, one having generally acidic spoil banks and the other having calcareous spoils. Proximate analysis of water, ash, crude protein, ether extract, cell-wall constituents, and nitrogen-free extract revealed few significant differences between plants growing on stripped and undisturbed (control) plots. Plants also were analyzed for 6 essential elements by emission spectrography. Levels of potassium were significantly higher in plants from control plots. Calcium levels were higher in plants from alkaline spoils, and manganese levels were higher in plants from acidic mined plots. Manganese levels exceeded 600 ppm in some plant samples from acidic spoil banks. Even when plants from stripped plots contained significantly less of a given element, levels were generally not low enough to indicate nutrient deficiency.

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Stripmining is a major environmental problem in Ohio, as in other coal producing states, because over large mined areas the original plant communities were destroyed. Some areas are so inhospitable to plant growth that attempts to restore vegetative cover by a variety of planting techniques and plant species have been unsuccessful.

In a random-sampling survey of surface-mined areas, the U. S. Department of the Interior (1967) estimated that only 25% of the sites observed were suitable for agriculture. The usefulness of these mined lands in the future can be questioned. It has been suggested that they might be utilized for wildlife and wildlife-associated recreation. Depending on substrate type, vegetation on mined lands may be less abundant and diverse and characterized by a plant community differing in composition from that of nearby undisturbed land. Nutritive levels in plant tissues from mined sites may differ from those of undisturbed lands. Our principal objective was to examine the effects of substrate, as altered by stripmining, on the nutritive quality of vegetation growing on such substrate and available as food for wildlife that inhabit these mined sites.

DESCRIPTION OF STUDY AREAS

Vegetation samples were obtained from study areas in Harrison and Perry Counties in east-central Ohio. These sites possess distinctively different types of overburden (Lindsay 1974). The important difference between the two study areas, for purposes of this investigation, was the contrasting pH levels of spoil banks.

The unglaciated Perry area has a mature topography with average relief of 61 m. Mean annual temperature is 10.8°C and mean annual precipitation is 91.8 cm. Total snowfall from December 1972 through March 1973 was 17.5 cm (U. S. Department of Commerce 1972, 1973). It is unusual for snowfall to persist for more than 1 week. The principal coal seam, No. 6 Middle Kittaning, occurred in two or three benches separated by highly acid, pyritic shales and clays (Limstrom and Merz 1951). The pH of stripped plots was 3.7 to 4.0, that of control plots 4.1 to 4.3. Mining of the

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sites began in 1948 and ceased in 1960 (Bookhout *et al* 1968).

Mature forests occupied most unstripped sites in Perry County. Dominant tree species were American beech (*Fagus grandifolia*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), white ash (*Fraxinus americana*), and several species of oaks (*Quercus* spp.) and hickories (*Carya* spp.). Understory vegetation consisted chiefly of reproduction of overstory species and sparsely distributed grasses (Gramineae) and forbs. Black locusts (*Robinia pseudoacacia*) were planted extensively on stipmine spoils because of their tolerance to low pH. Other common species on stripped sites were silver maple (*A. saccharinum*), red oak (*Q. rubra*), large-toothed aspen (*Populus grandidentata*), goldenrod (*Solidago* spp.), and blackberries (*Rubus* spp.).

Unglaciated Harrison County is characterized by steep slopes and long, sinuous ridges, some of which reach 396 m in elevation (Brant and DeLong 1960). Mean annual temperature is 10.9°C; mean annual precipitation is 101.5 cm. Total snowfall from December 1972 through March 1973 was 15.2 cm (U. S. Department of Commerce 1972, 1973). Mining on the study area took place between 1948 and 1955.

The principal coal seam in Harrison County is Pittsburgh No. 8, and on the study area it lies under 4.6 m of limestone and 4.0 m of shale. Overburden is shaly-limestone-clays (Limstrom 1950). The pH of stripped plots was 6.7 to 7.6; pH levels of 4.1 to 4.6 on unstripped (control) plots were similar to those of undisturbed sites in Perry County. Erosion was less severe on the Harrison County plots than on the Perry County plots.

The Harrison County stripped areas we studied each contained a semi-graded (flat-topped) bank more lushly vegetated with forbs and grasses than any spoil banks we observed in Perry County. Woody species on the Harrison County stripped and unstripped areas were much the same as in Perry County.

MATERIALS AND METHODS

We selected six 16.2 ha plots on each of the two study areas. Four plots were on stripmined sites and were selected by random sampling, with the prerequisite that each plot have at least 75% of its surface affected by stripmining. Two control plots on undisturbed land were subjectively selected for vegetation representative of the area and proximity to the four stripped plots.

Two 274.2 X 6 m belt transects were laid out on each plot and divided into three 91.4 m segments; individual species (or combined forbs or grasses) collected from each segment comprised a sample and were kept separate for statistical treatment. Transects were established along valleys, along ridgetops, and on slopes parallel to ridgetops to offer as much diversity in site and vegetation types as could be obtained within the confines of the 16.2 ha plot.

We believed it necessary to strike a balance between collecting those species that occurred most frequently along the transects and those that could be found on both stripped and control plots. This presented some difficulty; woodlots on the stripped areas were in an earlier stage of succession than those on the control areas, and it was virtually impossible to find black locust, aspen, and silver maple on control areas. Nevertheless, black locust was collected because it is so common on stripped lands. Three control areas were wooded, so we could not collect enough grasses from control plots to carry out the desired statistical analysis.

The terminal 12–15 cm of forbs (48 genera) and grasses (7 species) were clipped. All forbs, including flowers and seeds, from each 91.4 m segment were combined into a single sample for analysis; grasses were treated similarly. Only the present year's growth was taken from woody species, from ground level to 1.5 m. Leaves and twigs were analyzed separately.

Collections were made in August (summer) and October (autumn) of 1972, and February (winter) and June (spring) of 1973. Samples were air-dried in opened paper bags, ground in a Wiley mill, and stored in polyethylene bags. All values presented are based on air-dry sample weights. To test whether air drying the samples affected crude protein values, we collected timothy (*Phleum pratense*), red clover (*Trifolium pratense*), and goldenrod, prepared four 1.8–2.2 g samples of each, and air dried (for 21 days, until weight did not change in 2 consecutive days) or oven dried (overnight at 70°C) two samples. There were no statistical differences ($P \leq 0.05$) in percent nitrogen between air dried and oven dried samples of any species, so air drying was considered an acceptable method of sample preparation.

Nutritive values were obtained by proximate analysis. Moisture, ash, and ether extract analyses followed the procedures of Horwitz (1970). Nitrogen, used to calculate protein values, was measured by the Kjeldahl method (Horwitz 1970). Cell contents were extracted by boiling samples in a neutral detergent solution to obtain values for cell wall constituents (CWC) (Van Soest and Marcus 1964).

The essential mineral elements phosphorus, calcium, potassium, magnesium, manganese, iron, copper, zinc, boron, and molybdenum were

TABLE 1

Nutritive levels of vegetation from stripped and control plots, Perry and Harrison Counties, Ohio, 1972–1973.

Variable	Sample Size	Percent								ppm	
		Protein	Fat	Cell-walls	NFE	P	K	Ca	Mg	Mn	Fe
						Forbs					
Treatment											
Stripped	148	9.2**†	2.5	46.6	25.1	0.27**	2.0**	1.0**	0.3	207.3**	182.0
Control	59	11.3	2.4	42.5	25.0	0.28	3.0	1.2	0.3	264.5	162.7
County											
Harrison	120	9.7*	2.3	45.2**	25.2	0.29**	2.2*	1.1	0.3	125.3**	183.6
Perry	87	9.9	2.7	45.7	25.0	0.25	2.4	1.0	0.3	359.1	166.7
Seasons		**	**	**	**	**	**	**	**	**	**
Interactions											
County-Season		**	—	**	**	**	**	**	—	—	**
Seasons-Treatment		—	—	*	**	—	*	—	—	—	—
County-Treatment		*	**	—	—	**	—	**	—	**	—
						Blackberry					
Treatment											
Stripped	77	9.3**	1.8	47.2	28.1**	0.28*	1.3**	0.8*	0.4	336.2*	141.1
Control	12	11.7	2.0	48.3	23.5	0.25	1.8	1.0	0.4	286.3	147.7
County											
Harrison	43	9.1	1.8	48.2	26.5*	0.27	1.5*	1.0*	0.4	105.9**	153.1
Perry	46	10.0	1.8	46.6	28.3	0.27	1.3	0.7	0.4	538.5	131.6
Seasons		—	**	**	*	**	**	**	**	—	**
Interactions											
County-Season		—	—	**	**	—	**	**	—	**	**
Season-Treatment		—	—	—	—	—	—	—	—	—	—
County-Treatment		—	—	—	—	—	—	**	—	**	—

TABLE 1. *Continued.*

Nutritive levels of vegetation from stripped and control plots, Perry and Harrison Counties, Ohio.

Variable	Sample Size	Percent								ppm	
		Protein	Fat	Cell-walls	NFE	P	K	Ca	Mg	Mn	Fe
						Red Maple Leaves					
Treatment											
Stripped	22	10.1**	3.4	27.7**	45.7	0.24	0.9**	1.0	0.3**	505.0**	165.4**
Control	26	9.3	2.9	30.6	45.1	0.27	1.0	1.0	0.2	605.1	115.8
County											
Harrison	24	9.8	3.0	29.6	44.9	0.28*	1.0	1.0	0.3**	510.6**	139.5**
Perry	24	9.6	3.2	28.8	45.9	0.23	1.0	1.0	0.2	607.9	137.6
Seasons		**	**	—	—	—	**	**	—	—	**
Interactions											
County-Season		—	—	*	*	—	—	—	—	—	—
Season-Treatment		—	**	—	—	—	—	—	—	—	*
County-Treatment		—	—	*	—	*	—	**	**	**	—
					Red Maple Twigs (Perry County only)						
Treatment											
Stripped	15	4.4	1.1	55.6	28.4	0.19	0.5**	1.0	0.0	572.1	70.5
Control	6	4.3	0.9	55.2	28.6	0.17	0.6	1.2	0.0	550.7	62.0
Seasons		**	**	—	—	—	**	*	—	—	—
Interactions											
Season-Treatment		—	—	—	—	—	—	**	—	—	—

†Numerical values are arithmetic means; presented to allow comparisons with data from similar studies.
$^*P<0.05$, $^{**}P\leq 0.01$. Tests of significance are of geometric means, *not* of the arithmetic means presented. Data were log-transformed to satisfy the assumptions of ANOVA. Therefore the resulting geometric means were tested.

measured at the Ohio Agricultural Research and Development Center, Wooster, by emission spectrography with a Jarrell-Ash spectrometer (Model 660402).

Soil samples were taken from two stripped plots and one control plot in each county. Six 20 cm cores were taken from each of the 2 transects on each plot. Collection sites were spaced along the length of the transect, and the 6 cores then were combined into a single sample. The Soil Testing Laboratory of The Ohio State University Cooperative Extension Service used a weak $CaCl_2$ solution to determine pH.

Data were analyzed with a three-way analysis of variance design (ANOVA) with unequal and missing cells. The main effects were treatment (i.e., stripped or unstripped) with two levels, county with two levels, and season with four levels. Two-way interactions were tested, but three-way interactions were found to be nonsignificant and were pooled with the mean square error for tests of main and two-way interactions effects. The linear model was:

$$Y_{ijkl}=M+T_i+C_j+S_k+TC_{ij}+TS_{ik}+CS_{jk}+E_{ijkl}$$

where T_i was the ith treatment $(i=1,2)$, C_j was the jth county $(j=1,2)$, S_k was the kth season $(k=1,2,3,4)$, E_{ijkl} was the error for the lth replicate of the ijkth cell, and Y_{ijkl} was the lth observation of the ijkth cell. The number of replicates per cell varied from 1 to 35. The above model assumed that all effects were fixed effects.

Counties were chosen to represent soil conditions and were not randomly selected from all possible counties in the coal producing regions of Ohio. Treated areas within a county were selected randomly, but control areas were selected to minimize the differences that may have existed prior to stripmining. Seasons cannot be considered a nested effect, because there is a correspondence between areas. Hence we have assumed a fixed effect model and are making inferences only about the areas studied, not the total stripmined areas of Ohio.

The REGR procedure of the Statistical Analysis System (Service 1972) was used to calculate the sums of squares and F-test significance levels for log-transformed data. The partial sums of squares (Draper and Smith 1966) were used. A logarithmic transformation was applied to correct for heterogeneity of variance and non-normality in the data.

The results of this ANOVA for the treatment effect were compared with a previous statistical analysis of the data (Lindsay 1974) that utilized the Wilcoxon rank sum test (Hollander and Wolfe 1973). Rank sums were calculated for the treatment effect in each of the eight season X county cells. For the plant species and variables discussed in our paper, ANOVA results indicated significant differences ($P \leq 0.05$) for the treatment factor in 19 instances; in 18 of these instances 1 to 4 of the 8 Wilcoxon tests were also significant at $P \leq 0.20$. The larger probability level was used to compensate for the smaller sample size of the eight Wilcoxon tests. Thus, we feel the log transformation adequately corrected the data for the assumptions of ANOVA.

RESULTS AND DISCUSSION

Crude protein levels were significantly higher in forbs and blackberry from control plots and reflected a seasonal trend (table 1). Levels were highest in spring, diminished through summer and fall, and were lowest in winter. For example, forbs and blackberry from stripped plots had respective mean levels of 14.2 and 15.9% protein in June and 5.4 and 5.3% in February (Lindsay 1974). Torgerson and Pfander (1971) found that Missouri summer and winter deer foods contained 15.0 and 5.4% protein, respectively.

Protein content of red maple leaves was similar to that in forbs and blackberry and was significantly higher in plants from stripped plots than from control plots (table 1); levels in red maple twigs were low, with a year-round average of less than 5.0%. Black locust leaves contained the highest levels of protein of all plants examined, with an annual average of nearly 20.0% (table 2). For all plant species analyzed, protein levels of 13.0% or more were common in spring. Black locust twigs were virtually the only plants sampled providing more than 6.0% protein in winter (Lindsay 1974). Despite its high protein content and widespread distribution, black locust rates low as a wildlife food (Martin *et al* 1951).

French and co-investigators (1956) reported a protein requirement in growing white-tailed deer (*Odocoileus virginianus*) of 13 to 16%, and Einarsen (1946) stated that 5.0% is the critical lower protein level for black-tailed deer (*O. hemionus columbianus*). Forages containing at least 12% (dry matter) digestible protein were judged satisfactory for young free-ranging cottontail rabbits (*Sylvilagus floridanus*) (Snyder *et al* 1976); this value is nearly identical to the requirements of 12.0% dietary protein for maintenance and 15.0% for growth by domestic rabbits (National Research Council 1966). Protein content of our study area plants appeared to be satisfactory during the growing season but seriously deficient in winter.

Ether extract (crude fat) was significantly higher in forbs from stripped plots (table 1). Forbs contained more

TABLE 2

Nutritive levels of mixed grasses and black locust leaves from stripped plots, Perry and Harrison Counties, Ohio, 1972–1973.

County	Sample Size	Percent								ppm	
		Protein	Fat	Cell-walls	NFE	P	K	Ca	Mg	Mn	Fe
				Grasses							
Harrison	32	8.6†	1.8	65.8	10.6	0.24	1.5	0.4	0.2	56	160
Perry	32	7.1	1.8	62.0	12.4	0.21	1.1	0.1	0.1	299	179
				Black Locust Leaves							
Harrison	18	18.6	2.0	34.3	28.1	0.25	1.5	1.7	0.3	32	159
Perry	54	20.7	2.4	36.1	29.4	0.32	2.0	0.8	0.3	283	132

†Numerical values are arithmetic means. Control data were lacking, so no statistical analysis was performed.

than 3.0% crude fat in summer, and red maple leaves contained even more in summer and fall. Blackberry and twigs of all tree species examined contained less than 2.0% crude fat in all seasons (Lindsay 1974). Ether extract levels were lower than the pooled summer and winter average of 5.7% in deer foods in Missouri (Torgerson and Pfander 1971).

Red maple leaves from control plots contained significantly more CWC than did those from stripped plots (table 1). In both forbs and blackberry, CWC exceeded 60.0% in winter. In spring and summer, values for both groups were lower, ranging from 31 to 47% (Lindsay 1974). Red maple and black locust leaves were lowest in CWC in all seasons (tables 1 and 2). CWC may be considered a negative component of the proximate analysis; that is, they have little food value except to ruminants, so high CWC indicate low nutritional value. Van Soest and Marcus (1964) observed a marked decrease in voluntary intake by dairy cattle when CWC of 9 species of grasses and legumes rose above 60.0%.

Nitrogen-free extract (NFE, the soluble carbohydrates), was significantly higher in blackberry from stripped plots than from controls (table 1). Red maple leaves contained highest NFE levels, more than 40.0% in all three seasons. In most instances NFE mean values ranged from 20 to 30% (Lindsay 1974). Grasses were lowest, generally containing less than 15% NFE in all seasons (table 2).

Interpretation of the ANOVA results for levels of essential mineral elements in vegetation from stripped versus control plots was complicated by the fact that the two stripped study areas had contrasting pH levels. Soil pH is a major factor in determining whether certain important minerals are present and available to the plant community. Phosphorus, for example, is least available in acidic soils because they contain more hydrated iron and aluminum oxides and fix phosphates more readily than do alkaline soils. Iron and aluminum phosphates are least soluble, and least available, below a pH of 5.5.

Forbs and blackberry from stripped plots contained more phosphorus than did control plants (table 1), probably because phosphorus, as well as other minerals, may occur in greater concentrations on recently mined land (i.e., unweathered substrate). The phosphorus content in forbs and red maple leaves from Harrison County was higher than in those from Perry County, probably the result of greater availability of phosphates to plant uptake in the calcareous substrate of Harrison County spoil banks.

Mean phosphorus levels ranged from 0.17% (red maple twigs) to 0.32% (black locust leaves) (tables 1 and 2). Torgerson and Pfander (1971) found mean phosphorus levels in Missouri deer foods of 0.25% in summer and 0.11% in winter. Smith and co-workers (1956) measured nutrient levels in browse from a wildlife area in North Carolina that supported a healthy white-tailed deer population; the mean value for phosphorus in vegetation collected during all seasons was 0.15%. Weaned white-tailed deer fawns require 0.25% phosphorus in the diet (Ullrey *et al* 1973), and domestic rabbits require 0.22% phosphorus (National Research Council 1966). Levels of phosphorus in the spoil bank plants we analyzed probably would meet the needs of resident mammals.

Calcium levels were higher in plants from control than from stripped plots in Perry County, whereas they were higher in plants from stripped plots in Harrison County (Lindsay 1974). These results were expected, based on pH levels in the two counties. The ANOVA showed forbs and blackberry from control plots contained significantly more calcium (table 1). For both groups there was a highly significant ($P<0.01$) county X treatment interaction, and blackberry from Harrison County contained significantly more calcium.

Calcium levels in grasses were generally low (table 2). Mean values for calcium in stripmine vegetation (table 1) were somewhat lower than the pooled means for calcium in deer browse of 1.4% found by Torgerson and Pfander (1971) and 1.3% by Smith *et al* (1956), but stripmine plants did contain more than the 0.40% dietary calcium requirement for growing deer (Ullrey *et al* 1973) and probably would meet the optimum dietary calcium level of 0.65% for bobwhite quail (*Colinus virginianus*) chicks reported by Wilson *et al* (1972).

The calcium:phosphorus ratio is of importance in animal nutrition. The desirable ratio lies between 1:1 and 2:1, but adequate nutrition is possible outside these limits. For calves, for example, ratios up to 7:1 in feed are satisfactory (Maynard and Loosli 1969). In few instances did the calcium:phosphorus ratio of plants from stripped plots exceed 5:1, and it ought to be satisfactory for animals utilizing plants from these spoil banks.

Potassium levels were significantly higher in plants from control plots (table 1). Overall, however, potassium levels were sufficiently high to indicate that this mineral was not lacking in vegetation from either stripped or control plots. Pasture grasses typically contain 1.2–2.8% potassium, alfalfa 1.5–2.2% (Church and Pond 1974). Forbs and grasses from our study areas had mean values of 1.06–2.95% potassium (tables 1 and 2). Levels were generally in excess of the potassium requirement of 0.6 to 0.9% for domestic rabbits (Hove and Herndon 1955).

Magnesium content of red maple leaves was significantly higher in Harrison than in Perry County and higher on stripped plots than on controls (table 1). Calcium and magnesium are usually the dominant exchangeable bases on the colloidal cation exchange sites, so neither element could be expected to be deficient in calcareous overburden. Magnesium mean values ranged from 0.04 (red maple twigs) to 0.37% (blackberry) in vegetation from stripped plots (table 1). Whether these levels are adequate for native animal consumers of vegetation is not known, but young domestic turkeys and chickens require 0.05% magnesium (National Research Council 1971) and domestic rabbits require between 0.03 and 0.04% magnesium (National Research Council 1966).

Significantly higher levels of manganese were found in plants from stripped plots than from control plots in Perry County; conversely, because of the calcareous spoils in Harrison County, significantly lower levels of manganese were present in vegetation from stripped plots than from controls (Lindsay 1974). Table 2 shows county mean values from spoil bank plots and the striking effect of substrate. Grasses and black locust leaves from Perry County contained 5 and 9 times as much manganese, respectively, as grasses and black locust leaves from Harrison County. The pattern was the source of the county X treatment interactions affecting the ANOVA for treatment effect (table 1). Averaging manganese levels obtained from plants from two such dissimilar substrates yielded a mean for the treatment effect that probably was representative of neither. On the other hand, means for the county effect were in line with a previous statistical analysis separating stripped and control plots by county, and they provided a better estimate of the actual manganese levels present. In the three instances in which the county effect was measured, ANOVA showed that mean manganese levels from Perry County plants were higher than those from Harrison County plants ($P<0.01$).

Some manganese levels in plants from Perry County exceeded 600 ppm; much lower levels were found in Harrison County plants. Maynard and Loosli (1969) reported that roughages used for animal feed contain 40 to 140 ppm manganese and that excess manganese depresses hemoglobin synthesis as a result of manganese-iron antagonism. Andrew and Hegarty (1969) found the "toxicity threshold value" of manganese (to plants) in four temperate pasture legume species ranged from 380 to 650 ppm in the dry matter of the tops. Although these data suggest that manganese levels of 600 ppm or more may be detrimental to plant and animal welfare, Smith *et al* (1956) reported manganese levels exceeding 600 ppm in 9 of 19 vegetation samples from a North Carolina wildlife area supporting healthy deer.

ANOVA provided further evidence of a tendency for iron levels to be higher on stripped plots and in Harrison County (table 1). The latter was an unexpected result, because iron, like manganese, is least available for plant uptake in calcareous soils. Iron commonly is found in association with coal seams, however, and, although the higher pH in Harrison County may have reduced its availability to plants, there was evidently sufficient iron in the spoil banks to provide plants with significantly more of this mineral than was available from undisturbed soils. All mean values for iron in vegetation from stripped plots in both counties exceeded the iron requirement (40 ppm) for chickens and ruminants (Maynard and Loosli 1969).

Data for boron (essential only to plants), copper, zinc, and molybdenum were not included here because there were few statistically significant differences between levels of these four elements in vegetation from stripped and control plots. Moreover, levels of these elements probably were adequate for nutritional needs, based on criteria from Maynard and Loosli (1969) and Underwood (1971).

CONCLUSIONS

Plants examined on our two study areas appeared to be deficient in readily digestible carbohydrates on both stripped and undisturbed land. This was especially evident in plants collected during winter, when cell wall constituents were generally around 60%. Crude fat levels were low on stripped and control plots throughout the year and protein levels were highest in spring and low in winter.

Results of the proximate analysis did not provide clear evidence that animals would be better nourished on either the mined or undisturbed land. These findings were similar to those of Lindlof *et al* (1974), who measured mountain hare (*Lepus timidus*) browse by proximate analysis and found little variation within plant species occupying different kinds of habitats. They found large differences between species, but nutrient differences within species tended not to be large. They concluded that many species are able, within limits, to keep the same chemical composition irrespective of soil properties. If the nutrient elements in different soils are in balance, little difference will be found in the nutrient composition of a given plant species growing on these soils. The striking deficiency symptoms of plants, as well as very high percentages of certain elements in plant tissue, are a result of large imbalances of soil nutrients.

The spoils studied apparently are not lacking in the elements essential for plants and animals. Phosphorus, potassium, calcium, magnesium, manganese, iron, copper, zinc, and molybdenum were present in plants from stripmined sites in concentrations generally at or above those reported in the literature as meeting the nutritional requirements of animals. Even when plants from control plots contained significantly higher amounts of potassium and calcium, levels in plants from stripped plots appeared to be adequate.

The possible presence of toxic concentrations of certain metals in stripmine vegetation should not be ruled out. In Perry County, manganese levels exceeded 600 ppm in some seasons for all plant samples except black locust and ash leaves and twigs (Lindsay 1974). This is a manifestation of nutrient imbalance resulting from acidic conditions on the spoil banks. Some stripmined areas have pH levels considerably lower than those in Perry County, indicating potentially more serious nutrient imbalances in such areas.

The complex question of whether a given area is suitable for wildlife habitation is not resolved by an assay of the chemical constituents of plants growing on the area. It also involves the species composition of the plant community and the palatability to wildlife of individual species present. The unvegetated spoil banks in both counties are evidence that adverse chemical and physical conditions prevent or retard plant recolonization, and some native species have not been able to return.

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