Illinois Academy of Science Transactions, Vol. 48, 1956

AQUATIC AND MARGINAL VEGETATION OF STRIP MINE WATERS IN SOUTHERN ILLINOIS

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Introduction

Mining coal by the stripping process destroys the original land surface and leaves a waste area characterized by parallel rows of spoil banks 10 to 30 feet high intermingled with pools of water ranging in size from a fraction of an acre to 16 acres. This surface water constitutes between 5 and 10% of the total stripped acreage on the 5 areas of study in Jackson, Williamson, and Perry counties. The 52 pools studied represent a relatively small sample from the approximately 22,000 acres of stripped land in southern Illinois.

Aside from the ecological significance of the revegetation of an artifically denuded site possessing unusual edaphic characters and imposing an extreme migration handicap, the purpose of this study was to increase the knowledge concerning these areas, thereby facilitating future management.

General Description of Area

The overburden of the coal seam, which is scooped from a narrow strip and deposited to the side to form the spoil, is primarily composed of calcareous shales and soil-sized particles. However, a slate stratum immediately overlying the coal seam contains quantities of sulfur and pyrites which upon oxidation and hydrolysis are a source of mineral acids. Unequal mixing of the various strata results in a wide range of pH values for the spoils and for the pools of water below. The intense erosion which occurs on the 40- to 60-degree slopes produces a narrow, mucky shelf around the perimeter of the pool. This heavy runoff carries into the pools calcium, magnesium, and sodium sulphates produced by the decomposing spoils which impart salinities of 200 to 4,000 parts per million. Eventually, volunteer growths of cottonwood (*Populus deltoides*), sweet clover (*Melilotus* spp.), wild lettuce (*Lactuca scariola*), cheat (*Bromus* spp.), goldenrod (*Solidago* spp.), and aster (*Aster* spp.) stabilize the spoils. (A record of each identification has been deposited in the Southern Illinois University herbarium, and the nomenclature follows Jones, 1950).

Effect of Hydrogen Ion Concentration

While the hydrogen ion concentration at values below 4.0 may in itself limit plant growth, the major function of this value is as an indicator of the behavior of certain essential minerals. Above the midpoint of the pH scale, cations such as calcium, magnesium, and potassium are more readily absorbed. As it facilitates anion exchange, the slightly acid medium is considered optimum for plant growth on soils,

TABLE 1.—Plant Distribution Correlated with Physico-chemical Characteristics of Strip Mine Waters in Southern Illinois.

	Age of pond, years	Frequency of occurrence	Vegetative growth	Tolerance to pH	Specific conductance, reciprocal megaohms at 25°C.	Fluctuation of water level, feet
SUBMERGED						
Potamogeton foliosus	4-30	57	profuse	6.4-8.6	1,000-5,000	1-5
Chara spp.	4-26	28	profuse	6.6-8.2	500-5,000	1-5
Potamogeton pusillus	6	2	profuse	7.0	3,000-4,000	3-5
Najas flexilis	22	2	profuse	7.5	500-1,000	0-2
FLOATING						
Potamogeton americanus	6-30	7	moderate	6.4-7.6	3,000-4,000	0-3
Potamogeton diversifolius	22	4	profuse	7.7-9.4	500-1,000	0-1
Nelumbo lutea	4	2	sparse	7.0	3,000-4,000	0-1
Jussiaea diffusa	6	2	sparse	7.5	2,000-3,000	1-2
EMERGENT						
Typha latifolia	3-30	66	profuse	3.0-8.1	1,000-5,000	0-2
Typha angustifolia	8-12	4	profuse	4.5-7.6	2,000-3,000	0-2
Eleocharis obtusa	4-22	38	moderate	3.4-9.4	500-3,000	1-3
Leersia oryzoides	10-14	10	moderate	6.4-7.8	500-3,000	0-1
MOIST SOIL						
Salix spp.	4-30	36	profuse	3.6-8.4	500-5,000	0-2
Andropogon virginicus	3-22	25	profuse	3.4-8.6	1,000-3,000	1-4
Paspalum circulare	22	4	profuse	3.5-3.6	500-1,000	1-6
Ludwigia alternifolia	22	2	sparse	9.4	500-1,000	1-3
RECESSION ZONE						
Polygonum pennsylvanicum	3-30	36	profuse	3.0-8.6	1,000-5,000	2-8
Echinochloa crus-galli	3-30	51	profuse	3.0-8.6	500-5,000	2-5
Cyperus erruginescens	8-22	28	moderate	3.4-8.4	1,000-5,000	2-8
Ammania coccinea	10-22	9	sparse	7.1-8.2	500-3,000	2-6

but waters are generally most productive when moderately alkaline.

The majority of the water areas studied exhibited pH values between 6.0 and 8.0 and were characterized by dense growths of narrow-leaved pondweed (*Potamogeton foliosus*) on the shallow alluvial shelf. A common associate of the narrow-leaved pondweed at pH values between 7.0 and 8.0 was stonewort (*Chara* spp.) also in a very profuse growth. At pH 6.6 the aquatic vegetation was much less dense, as indicated by the widely spaced individuals of floating-leaved pondweed (*Potamogeton americanus*) which is slightly more tolerant to acidity than the narrow-leaved pondweed. Only emergent species occurred in waters with pH values below 6.4 (Table 1).

Effect of Changing Water Levels

Instability of the water table characterized even the large lakes which exhibited a recession of one to two feet during the dry summer. In some of the smaller ponds the water levels dropped as much as eight feet. These extreme fluctuations resulted from the restricted size of the watershed, the absence of an overflow, the lateral movement of subsurface water through the porous spoils, and the normally high rainfall in the spring coupled with a hot dry summer.

Rise or fall of the water level early in the growing season appeared detrimental to the zone of willows (*Salix niger*, *S. interior*, and *S. amygaloides*) which occurred immediately above the shoreline border of broad-leaved cattail (*Typha latifolia*). This area would then be occupied by broomsedge (*Andropogon virginicus*) which withstood early spring submergence. Fluctuations of the magnitude of three feet were beyond the wide tolerance limit of cattail and favored the development of moist soil annuals on the barren recession zone, while the winter pool level was usually marked by plants more typical of the upper slopes, such as sweet clover.

Wild millet (*Echinochloa crus-galli*) was the most frequently encountered of these moist soil annuals. Having the ability to adapt its growth period to the duration and seasonal interval of favorable moisture conditions, it was found in all stages of growth throughout June, July, and August. Largeseed smartweed (*Polygonum pennsylvanicum*) and straw-colored sedge (*Cyperus ferruginescens*) were less common on these exposed shores, seemingly being dependent for their establishment upon a recession of the water during April or May. Scattered individuals of red loosestrife (*Ammania coccinea*) occurred in the late summer recession zone on five sites.

Rice cutgrass (*Leersia oryzoides*) was associated with open stands of cattail and indicated a stable water level throughout the growing season.

Effect of Salinity

The high mineral concentrations of these waters do not necessarily influence the floristics, although the three most productive and frequently encountered hydrophytes, *Typha latifolia*, *Chara* spp., and *Potamogeton foliosus*, are reported by McAtee (1939) to tolerate salinities of 2,500 parts per million. The close correlation between salt concentration and plant distribution in coastal areas is attributed to sodium chloride as the major constituent of sea water. A particular group of plants, the halophytes, are able to incorporate this substance in their cytoplasm while other plants exclude this salt and are inhibited by this osmotically active material which interferes with the uptake of water. Any injurious effects of the high salt concentrations in the study pools would ionize within the plant cell as the major salts, calcium and magnesium sulphates, are secondary plant nutrients and are readily absorbed. In strip mine lakes possessing normally high specific conductances of 2,000 to 3,000 reciprocal megaohms (at 25°C.), water primrose (*Jussiaea diffusa*) made poor vegetative growth but grew luxuriantly at a value of 300 reciprocal megaohms which is approximately that of naturally occurring bodies of fresh water. An intolerance to high salinity was also reflected by the leaf size of American lotus (*Nelumbo lutea*), which averaged one-third normal size in these salty lakes.

Effect of Dissolved Oxygen

Lewis and Peters (1954) found high dissolved oxygen values (8 to 15 ppm.) in both the epilimnion and the hypolimnion of strip mine waters in southern Illinois. They attributed this condition to infertile waters with a low biochemical oxygen demand and clear water which permitted photosynthesis in the thermocline. Laing (1941) found that *Typha* and *Scirpus* shoots grew best in an atmosphere of 5 to 10% oxygen, whereas *Nuphar, Peltandra,* and *Pontederia* were much less tolerant to aeration. He concluded that semi-submerged plants inhabit a particular habitat on the basis of oxygen requirements for respiration and growth.

The marginal bands of cattail ascend the banks in seepage areas around the pools, but the upward limit is determined by the duration of the aeroperiod. The high dissolved oxygen in the pools permitted the *Typha* community to invade water depths of two feet. In one flooded lake a localized colony was growing in four feet of water with its leaves extending five feet above the water's surface. Another lake contained cattail seedlings growing in ten inches of water.

Effect of Turbidity

The paradox of the intensively eroding watershed and the crystal clear pools below is partially explained by the filtering action of the ferric oxide precipitates and the flocculation of the negatively charged soil particles by positive ions. The spoil banks protecting the pools from agitation by the wind and the moderating influence of thermal stratification on water movements also contribute to the rapidity with which the alluvial material is removed from suspension. This deposition accumulates on the foliage of submerged vegetation, forming a light obstructing coat a sixteenth to an eighth of an inch thick. This interference is reflected chiefly in reduced vegetative growth, as depth of distribution is restricted by the sheer drop-off along the outer edge of the alluvial shelf.

Many of the pools contained algal

growths which imparted a dark greenish-brown color to the water. The very acid lakes were readily distinguished by their bright green appearance, probably resulting from an increased solubility of an iron compound.

Effect of Age of Pool

The range of variation which can be expected when a correlation is made between chemical characteristics and age of the water is best exemplified by a series of small ponds on the oldest strippings in the Pyatt area. This group possessed the lowest salinities and the most extreme pH values encountered, with the exception of a sterile pond which received drainage from a coal dump and exhibited a pH of 2.3. The acid pools with a pH of 3.5 and

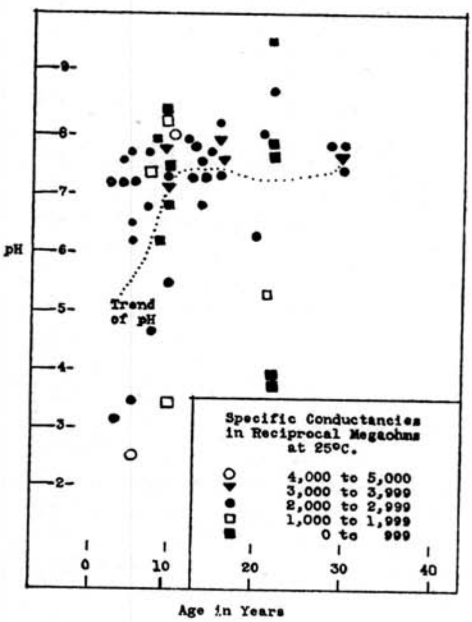

Fig. 1.—Correlation of salinity and pH with age of strip mine pools in southern Illinois.

a specific conductancy of 800 to 900 reciprocal megaohms contained no submerged vegetation. The high-water level of these acid pools was marked by a border of round-seeded paspalum (*Paspalum circulare*) and wild millet, with sapling willows higher up on the slopes. Blunt spikerush (*Eleocharis obtusa*) occurred as scattered tufts on the moist soil and in the shallow water. Paradoxically, though this spikerush was frequently encountered in open stands of cattail, it was most robust in this extremely acidic habitat.

Within 50 yards of the acid pools, large willows shaded dark coffee-colored waters containing small-leaved pondweed (*Potamogeton diversifolius*). A localized colony of Small's spikerush (*Eleocharis smalli*) bordered one of the pools which had a pH of 7.7. An adjacent pool with the extreme pH of 9.4 had its winter level marked by rice cutgrass, blunt spikerush, and seedbox (*Ludwigia alternifolia*). Another pond in the same vicinity was similarly heavily shaded by willows and exhibited the same low specific conductance of 100 to 200 reciprocal megaohms as the other two pools. It differed by having a pH of 7.5 and being filled with a luxuriant growth of bush naiad (*Najas flexilis*).

The marked deviation in vegetational aspects of this group of pools from other waters of different ages probably reflects unusual site conditions rather than any successional trends. The selection of the 52 study pools on the basis of variation in floral composition and the inclusion of larger bodies of water whose chemical qualities would be slow to change prevents an accurate analysis of aging. A trend toward neutrality or slight alkalinity is indicated by Figure 1, but salinities show little variation with age.

Migration of Plants

The initial invaders of newly created bodies of water are *Typha* and *Potamogeton foliosus* (McAtee, 1939). The wind-disseminated seeds of willows and cottonwoods, as those of cattail, possess a similar advantage for invading sterile soils. A prime requisite of any migrant is the presence locally of a parent colony which will provide an abundance of disseminules. An example is narrow-leaved cattail (*Typha angustifolia*) which was reported by Riley (1954) as bordering strip mine lakes in Ohio. Its infrequent distribution in southern Illinois precludes it as an important element in the strip land vegetation, even though it was competing successfully with broad-leaved cattail in two study areas. Three species which may be incapable of migrating into the strip mine lands in southern Illinois and which may be worth introducing because of their value for wildlife are: soft stemmed bulrush (*Scirpus validus*); wild rice (*Zizania aquatica*); and marsh smartweed (*Polygonum coccineum*).

Fertility of the Area

The stripland is apt to contain higher amounts of phosphorus and potassium than the original farmland, though the fresh spoils are deficient in nitrogen and devoid of organic matter (Limstrom and Deitschman, 1951). Three lakes which had been fertilized for fish production contained the better algal growths, but the marginal aquatic plants seemed little affected. Largeseed smartweed, growing on rich alluvial soils at the Carbondale reservoir, reached a height of seven feet, but the largest specimens observed on striplands were four feet tall, and the majority of the stands were about three feet in height. The cattail borders around the stripland waters compared favorably in stature and density with similar stands at Crab Orchard Lake, except that the width of the marsh area was restricted by the steepness of the spoil banks composing the shoreline of the stripland pools. The dense beds of pondweeds, stonewort, and naiad were in marked contrast to the meager growths of submerged aquatics in the turbid waters along the wave eroded shoreline of Crab Orchard Lake.

Summary

The majority of the 52 stripland pools studied exhibited pH values between 6.0 and 8.0 and were characterized by dense growths of narrow-leaved pondweed (*Potamogeton foliosus*) and stonewort (*Chara* spp.) on the shallow alluvial shelf.

Extreme water fluctuations in some of the smaller ponds were inimical to the shoreline border of cattail (*Typha latifolia*) and favored the development of moist soil anuals such as wild millet (*Echinochloa crusgalli*), largeseed smartweed (*Polygonum pennsylvanicum*), and straw colored sedge (*Cyperus ferruginescens*) in the barren recession zone.

The high concentrations of minerals in the stripland waters, primarily calcium and magnesium sul-

phates, apparently restricted the development of water primrose (*Jussiaea diffusa*) and American lotus (*Nelumbo lutea*).

High values of dissolved oxygen (8 to 15 parts per million) favored the growth of cattails and permitted the development of cattail seedlings in 10 inches of water.

The filtering action of the ferric oxide precipitates and the flocculation of the negatively charged soil particles by positive ions keep the pools crystal clear below the intensively eroding spoil banks.

There was no indication of a floral succession as the initial invaders, *Typha* and *Potamogeton foliosus,* were adapted to the trend of the waters to neutrality or slight alkalinity.

Densities of the submerged and emergent aquatic vegetation indicated a high fertility for the waters, but the steep spoil banks and the resulting narrow zones favorable for plant growth sharply curtailed production.

Acknowledgments

Appreciation is expressed to Dr. John W. Voigt, Department of Botany, and Dr. Willard D. Klimstra, Department of Zoology, Southern Illinois University, for editing this manuscript, and to Dr. William M. Lewis, Department of Zoology, Southern Illinois University, and Mr. Charles Peters for their assistance in determining hydrogen ion concentrations and specific conductances.

The investigations were made while I was a research assistant on Project No. 23 of the Cooperative Wildlife Studies. This research was part of the Strip Mine Investigations in which Southern Illinois University, Truax-Traer Coal Co., Illinois Coal Strippers' Association, Wildlife Management Institute, Sport Fishing Institute, United States Forest Service, Illinois Natural History Survey, and Illinois Department of Conservation are cooperating.

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