BIOTIC DEVELOPMENT COMPARISONS OF A WETLAND CONSTRUCTED TO TREAT MINE WATER DRAINAGE WITH A NATURAL WETLAND SYSTEM[1]

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Abstract: Using 5-yr of baseline data from a constructed wetland, we compared the biotic changes in this wetland to conditions in a natural wetland to determine if biotic development patterns were similar. The constructed wetland was built in 1985 to treat a coal mine discharge and was planted with broadleaf cattail (*Typha latifolia*) within the three-cell, 0.26 ha wetland. The natural wetland was also dominated by broadleaf cattail in the emergent zone and was 0.17 ha in size, excluding the adjacent pond. The natural wetland was located immediately downstream from the constructed wetland and received comparable water flows. Species richness in permanent quadrats of the constructed wetland declined over the study period, while cattail coverage increased. Plant species composition diversified at the edges, with several species becoming established. The constructed wetland deepened and expanded slightly in area coverage during the study period. The constructed wetland supported herptofaunal communities that appeared more stable through time than those of the natural wetland and sustained a rudimentary food chain dependent upon autotrophic algal populations. Despite fundamental differences in substrate base, morphology, and water flow patterns, biotic trends for the constructed wetland coincided with succession-like patterns at the natural wetland. We suggest that further shifts in the biotic composition of the constructed wetland are likely, but the system should continue to persist if primary production meets or exceeds the microbial metabolic requirements necessary to treat mine drainage.

Additional Key Words: cattail, *Typha*, succession, herptofauna

Introduction

Construction of wetlands for mine drainage treatment is a widely used reclamation practice, despite gaps in the present understanding of how these systems function and uncertainty about how they will persist through time (Wieder 1989). Several authors have alluded to the importance of hydrologic patterns for the maintenance and stability of constructed wetlands (Odum 1987; Niering 1989, 1990; Kusler and Kentula 1990). Fluctuations in water levels are inherent to the integrity of any wetland, resulting in E. P. Odum's (1971) concept of wetlands as pulsing systems. Niering (1990) has indicated that predictable changes in the vegetation of constructed wetlands are probably not possible due to continual changes in hydrology, and that the objective of reclamation efforts should be the establishment of "self-perpetuating systems" and not specific vegetation types.

Cairns (1985) indicated that a thorough understanding of the successional processes in constructed wetlands is necessary for establishment of systems that perpetuate through time without periodic intervention or maintenance. However,

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application of traditional concepts of succession to wetlands have failed to fully explain vegetational changes (Mitsch and Gosselink 1986). The use of the terms succession" and "climax community" are no longer recommended when addressing wetland plant communities. Niering (1987) has suggested that these terms be replaced by "biotic development" and "steady state," respectively, relative to cyclic changes in wetland vegetation and oscillations in hydrologic flow.

The interpretation of the vegetation mosaic in mine drainage wetlands is complicated because these sites are without a fully developed soil column (Kusler 1990) and are initially established with transplanted plant species (Hedin 1989). Broadleaf cattail (Typha latifolia) has been most frequently planted (Hedin 1989), and most sites start out with monotypic stands. Niering (1989) has postulated that continued self-maintenance of these wetlands may be due to superior competitive capabilities of cattail and/or allelopathic chemical inhibition of colonizing plant species. The absence of seed sources in the compost substrate, coupled with deeper water in many systems, further delays establishment of additional plant species. Consequently, long-term data on changes in plant community composition for mine drainage wetlands are needed to determine whether ingress of colonizing plant species is possible and/or preferred in wetlands where Typha has been planted as the dominant founder species.

In this paper we report the floral and faunal changes over a 5-yr period in a wetland constructed to treat a coal mine discharge. These findings are compared with data for a natural wetland on an abandoned beaver impoundment, immediately downstream from the construction site, to determine if biotic development in a nearby natural wetland could be used to predict changes over time in a constructed wetland. The data set used in this assessment represents a synthesis of previously reported findings with heretofore unpublished results.

Study Sites

Construction of the mine drainage wetland (Simco #4) was completed in November 1985 in Coshocton County, OH (Stark et al. 1988). The substrate in the three-celled wetland consisted of mushroom compost. Broadleaf cattail rhizomes were transplanted at a density of three to four rhizomes per square meter. The wetland was initially 0.26 ha in size and was receiving a deep mine discharge with a pH near 6.0 and an iron loading of 80 to 241 mg/L. Flow rates through the wetland average 328 L/min, but fluctuate with seasons. Overall, water treatment efficiency has improved with the age of the wetland (Stark et al. 1990).

The natural wetland developed on an abandoned beaver dam impoundment located directly downstream from the constructed wetland system. The natural wetland was 0.17 ha in size and was connected with a pond immediately downstream from the wetland. The wetland supported an emergent plant community dominated by broadleaf cattail. Hydrologically, the natural wetland received essentially the same water volume as that of the constructed wetland as only a series of three sedimentation ponds separated the two sites. The water chemistry in the natural wetland was improved by the upstream treatment of the mine drainage in the constructed wetland system. Mining activity ceased in the vicinity of the natural wetland in 1961, but unfortunately no historical information is available on the beaver dam and its wetland. The Simco #4 Mine began operation in 1970 and was sealed in 1979, with water treatment for the discharge commencing in 1980.

Methods

Forty permanent vegetation quadrats, 0.5 m^2 in size, were established in a grid pattern in the constructed wetland in 1985. The vegetation was annually inventoried from 1986 through 1990 for species coverage (Daubenmire 1970). Beginning in 1987, cattail density in numbers per square meter was also quantified (Stark et al. 1990). In August 1988, the natural wetland vegetation was inventoried. Seventeen 1 m^2 quadrats were randomly located. Vascular plant species were identified, and their percent cover was recorded. Cattail density was quantified as in the constructed wetland.

Surveys for reptiles, amphibians, and mammals were conducted at both the constructed and natural wetlands from May 19 to 25 and June 10 to 15 in 1988, 1989, and 1990. All reptiles, amphibians, mammals, and signs of each were surveyed in the same manner (Lacki et al 1991a, 1991b). Coefficients of variation (CV) were then derived for total abundance and species richness (i.e., number of species), with data for reptiles and amphibians combined (herptofauna) and examined separately from those for mammals. Coefficients of variation are computed by taking the standard deviation as a percentage of the mean. Comparison by this approach demonstrates relative stability among mean values by removing any size or scale factor (Sokal and Rohlf 1969).

Results and Discussion

Thirteen vascular plant species were found in the permanent quadrats in the constructed wetland. Six of the 13 species were found at coverage values of 2% or greater for at least one growing season (Table 1). Besides broadleaf cattail,

Table 1. Percent cover of vascular plants and algae at the constructed and natural wetlands with species whose coverage values exceeded 2% in at least 1 sampling year. The natural wetland was sampled in 1988 only.

Species	Constructed Wetland 1986	1987	1988	1989	1990	Natural Wetland 1988
Typha latifolia......	30	42	54	62	[1]	30
Leersia oryzoides....	4	22	11	1	6	20
Algae................	5	12	3	12	0	0
Lemna minor..........	4	2	5	1	1	0
Alisma aquaplantago..	0	1	[2]	5	0	0
Phalaris arundinacea.	[2]	2	0	0	0	0
Eleocharis sp........	0	0	0	0	0	11
Impatiens biflora....	0	0	0	0	0	7
Carex sp.............	0	0	0	0	0	5
Polygonum sagittatum.	0	0	0	0	0	3
Eupatorium maculatum.	0	0	0	0	0	3
Scirpus cyperinus....	0	0	0	0	0	3

[1]Not measured for that particular year.

[2]Found at less than 1%.

only rice cutgrass (Leersia oryzoides) and duckweed (Lemna minor) consistently occurred in the quadrats across the 5-yr of study. A general trend of declining richness in the number of vascular plant species has occurred with time in the constructed wetland quadrats. The number of species recorded in quadrats from 1986 to 1990 was 8, 9, 6, 4, and 3, respectively. This decline does not reflect changes along the edge of the wetland, where several herbaceous and woody species have volunteered. Concurrent with the decline in species richness in the sample quadrats, the wetland depth increased and a slight increase in area occurred as the water surpassed the tops of the berms, particularly in the first cell.

The natural wetland was also dominated by broadleaf cattail and rice cutgrass, but differed from the constructed wetland in having a strong representation of three additional species: spikerush (Eleocharis sp.), touch-me-not (Impatiens biflora), and sedge (Carex sp.). The natural wetland also supported a richer vascular plant species community as 23 species were identified as present in at least one quadrat, with three additional dicot species detected but not identified. The natural wetland exhibited three zones or belts of vegetation along a gradient running from the drier wetland vegetation, near the source where a portal provided water from the upstream sedimentation ponds, to the ponded water adjacent to the natural wetland. These vegetation belts were reflected in shifts in the number of vascular plant species recorded in quadrats (fig. 1). Species richness was low adjacent to the

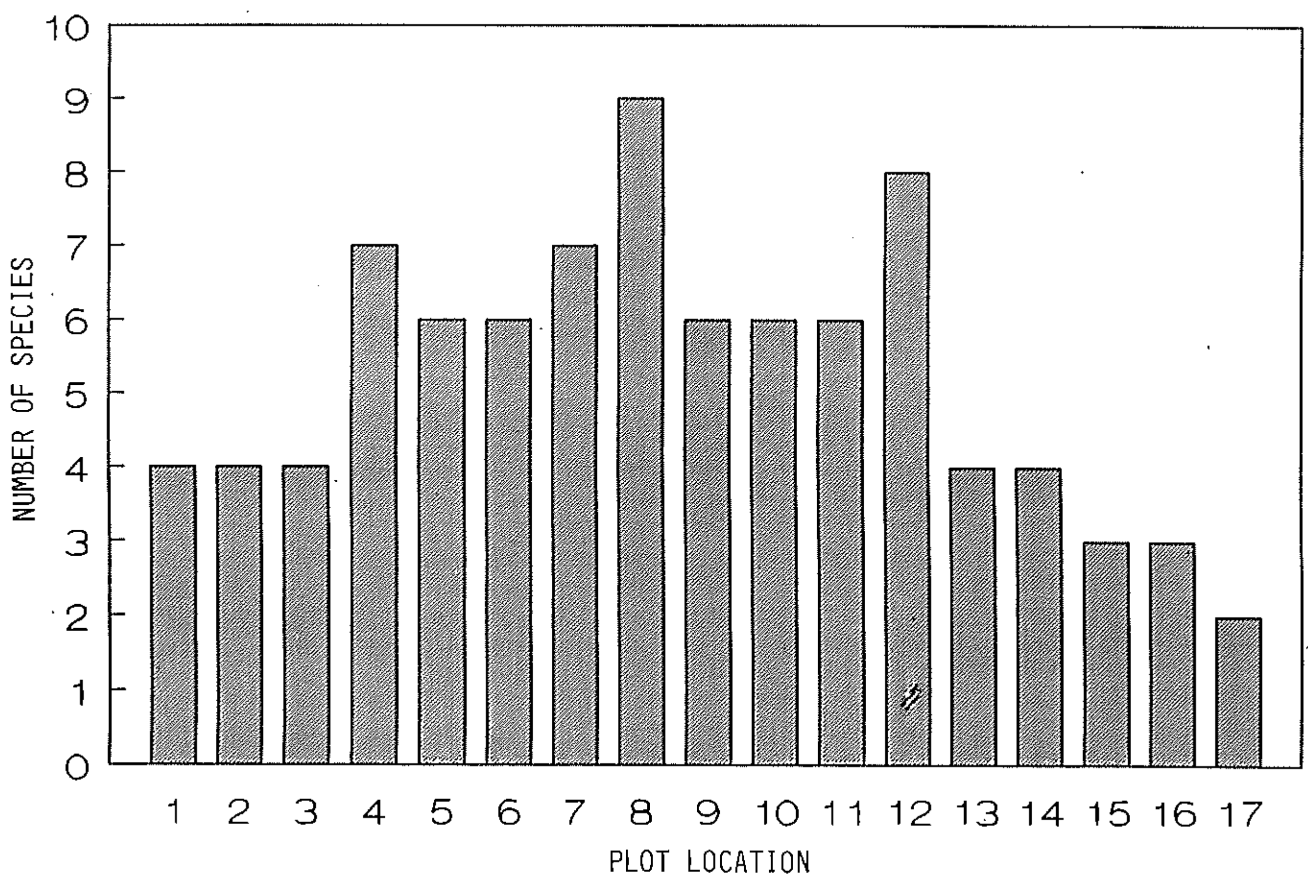

Figure 1. Number of species recorded per quadrat for samples obtained in the natural wetland, summer 1988. Plot locations represent a gradient starting from the upstream end (1) and continuing downstream to the edge of the wetland adjacent to the ponded water (17). Vegetation belts are noticeable by shifts in species richness at quadrat 4 and quadrat 12.

terrestrial habitat, increased to a maximum in the midportion of the wetland, and declined again as the wetland encroached upon the ponded water. At the upstream end, the natural wetland was more channelized and contained a firm substrate. Soils became more loosely compacted in a downstream direction, being extremely soft and unconsolidated adjacent to the ponded water. At this end the natural wetland exhibited an overall appearance not unlike that of the constructed wetland, with a reduced species richness and very deep mucky soils. The downstream end of the natural wetland was dominated by broadleaf cattail, rice cutgrass, and wool grass (Scirpus cyperinus).

Coverage values for broadleaf cattail increased in the constructed wetland as the system aged, surpassing the value for the natural wetland in 1988 by an additional 19%, suggesting that dominance by broadleaf cattail was increasing through time. Cattail density fluctuated among years in the constructed wetland, but remained at a density greater than that in the natural wetland across all years sampled (fig. 2). Narrowleaf cattail (Typha angustifolia) was observed to first invade the constructed wetland in 1988 and has continued to increase in area coverage since, particularly at the edges of the wetland cells. This species was absent from the permanent quadrats, thus actual coverage values are unavailable. Presently, narrowleaf cattail appears to be outcompeting broadleaf cattail at a microsite level. Algae was evident throughout the manmade wetland in the vegetation and vertebrate sampling. The four genera of algae recorded in the constructed wetland were Chlamydomonas, Euglena, Microspora, and Oscillatoria.

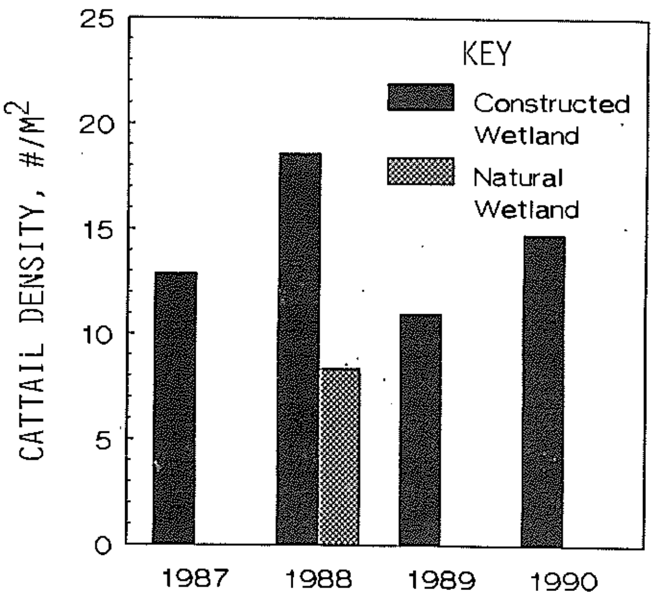

Figure 2. Density of cattails (number of stems per square meter) by year for the constructed and natural wetlands. (Natural wetland sampled in 1988 only.)

The presence of algae in the waters of the constructed wetland is probably essential to development of a food chain network. The constructed wetland is used as breeding habitat by green frogs (Rana clamitans) and gray tree frogs (Hyla versicolor), with tadpole larvae of both species present in the constructed wetland (Lacki et al. 1991b). Tadpoles of these species are herbivorous and depend heavily on algal food sources. A large amount of rubble and rock debris was also located in close proximity to the constructed wetland, providing denning habitat for an abundant snake population (Lacki et al. 1991b). Several snake species were found using the constructed wetland, including the northern water snake (Nerodia sipedon), eastern ribbon snake (Thamnophis sauritus), and northern black racer (Coluber constrictor). Exploitation of the abundant frog populations in the constructed wetland by snakes, which also utilize the adjacent denning habitat, contributed to the diversity of the herptofauna (Lacki et al. 1991b). Other predators, such as raccoons (Procyon lotor) and muskrats (Ondatra zibethicus) undoubtedly used these frog populations. Muskrats are commonly considered to be herbivores, although consumption of frogs has been documented.

Examination of CV values showed the natural wetland to support a more variable herptofaunal community than the constructed wetland, particularly in abundance levels, where the standard deviation across sample periods exceeded the value for the mean (table 2). During periods of low rainfall a noticeable surface water depth remained visible in the constructed wetland; this may be an important factor in sustaining the abundant frog populations and subsequently the rich variety of snakes inhabiting this wetland. The natural wetland appeared much more susceptible to "drying out" in times of limited rainfall, such as summer 1988. Data for mammals indicated the two sites to be comparable overall, with the natural wetland showing slightly higher variability in species richness. No obvious patterns emerged to permit a ready explanation for this discrepancy (Lacki et al. 1991a).

Table 2. Coefficients of variation (CV) for abundance and species richness of herptofauna and mammals at the constructed and natural wetlands, 1988, 1989, and 1990 combined. All measures based on 6 survey periods per site.

Taxon by wetland type	Abundance (CV)	Species richness (CV)
Herptofauna		
Constructed...	35.9	32.4
Natural.......	102.0	41.3
Mammals		
Constructed...	48.7	23.3
Natural.......	43.9	34.8

Several fundamental differences existed between the constructed and natural wetlands. The constructed wetland was manually planted, thus modifying substantially the early stages in biotic development. With its volunteered vegetation, the natural wetland composition was more reflective of typical patterns found for Typha-dominated wetlands. The natural wetland had available a long length of time for colonization, although the age of the beaver dam is unknown. Substrate texture was primarily silt and organic matter in the natural wetland, whereas the constructed wetland was based upon mushroom compost with an accumulation of iron precipitates. The accumulation of metallic precipitates may inhibit colonizing plant species, but this is an area that requires further exploration. The natural wetland exhibited an irregular morphology, with water flow tending to meander through the site in defined channels. Morphological and hydrologic patterns for the constructed wetland were much more regular.

Kadlec (1989) has found that for wetlands constructed to treat secondary sewage, plant diversity declined with age of the wetland. He suggested that systems designed to maintain continual water flow and pollutant inputs favored cattails over other vascular plant species. Our data for the constructed wetland support this finding (table 1). Observations at the constructed wetland indicate that the water increased in depth and the system expanded in surface area. These hydrologic changes offer opportunities to examine responses by the peripherally established vegetation.

In contrast to the simplification of the vegetation at the constructed wetland, amphibian populations were afforded more optimal habitat conditions because of the availability of a free water surface. The stable measures of abundance and species richness observed at the constructed wetland support this contention (table 2). We predict that, as long as source water quality permits reproduction by frogs, wetlands constructed for the treatment of mine water drainge will sustain frog populations. Brooks et al. (1987) indicated that it is impractical to expect treatment wetlands to provide habitat for wildlife. Based on the performance of the Simco constructed wetland (Lacki et al. 1991a, 1991b, 1991c), we contend that such a position is premature and that each wetland construction project should be evaluated for its wildlife habitat potential.

Future effects of changes in the constructed wetland on other wildlife inhabiting the site is unclear. Meadow jumping mice (Zapus hudsonius) have been recorded at the constructed wetland in the grassy habitats adjacent to the wetland (Lacki et al. 1991a). Expansion of the wetland will likely lead to an elimination of this cover type and a loss of this species from the immediate vicinity. Wetland expansion will also lead to input of iron-laden water into nearby vernal pools and pockets of unimpacted water located adjacent to the constructed wetland. The impact of a changed water quality in these microsites on other anuran species that do not use the constructed wetland for larval development remains unknown (Lacki et al. 1991b). These species include bullfrogs (Rana catesbeiana), pickerel frogs (R. palustris), American toads (Bufo americanus), and Fowler's toads (B. woodhousei). All other wildlife species recorded in the vicinity of the wetland should remain unaffected by wetland expansion.

More long-term studies are needed to fully evaluate the ultimate fate of broadleaf cattails in constructed wetlands. Although cattails are viewed as highly adaptive and capable of invading almost any wetland construction project (Odum 1987), data concerning cattail responses to water level changes are varied. Kadlec (1989) and this study found cattail respond favorably to sustained water depths. The possibility exists that in constructed wetlands where limited fluctuations in hydrologic patterns occur and iron precipitates accumulate, cattails may eventually decline in abundance if the precipitates suffocate the plants or form concretions at the surface. The time frame involved with such a phenomenon is unclear. Substrate consistency and water depth may also be important for the establishment of invading species, although comparable patterns of cattail dominance and species richness were observed in both the natural and constructed wetlands where a deep unconsolidated substrate occurred. Invasion of the Simco constructed wetland by narrowleaf cattail may reflect a lack of autotoxic effects from broadleaf cattail on germination and development of other Typha species (Sharma and Gopal 1978).

Wyngaard (1985) has suggested that wetlands be viewed from the perspective of performance, with wetland health assessed by examining wetland processes for possible malfunction. Bedford and Preston (1988) have indicated that optimization of all wetland functions within a given system is unrealistic, and Garbisch (1989) has pointed out that even existing wetlands seldom, if ever, maintain all wetland functions at a meaningful level. Alternatively, Cairns and Pratt (1985) recommend that constructed wetlands should only be expected to fall within the range of variability observed for natural wetlands. Based on the above arguments, we suggest that despite fundamental differences in substrate base, morphology, and water flow patterns, biotic trends for the constructed wetland coincided with succession-like patterns at the downstream end of the natural wetland. Further, the wildlife habitat utilization and food chain components were verified for the Simco wetland, documenting additional wetland functions for this system. A paucity of vascular plant species may be an artifact of the design of treatment wetlands, but Niering (1990) has indicated that wetlands should not be expected to support identical plant compositions, regardless of similarity in design, hydrology, and location within the landscape framework. We anticipate that further shifts in the biotic composition of the constructed wetland are likely, but the system should persist if primary production meets the microbial metabolic requirements for mine drainage treatment.

Literature Cited

Bedford, B. L., and E. M. Preston. 1988. Developing the scientific basis assessing cumulative effects of wetland loss and degradation on landscape functions: status, perspectives, and prospects. Environmental Management 12(5):751-771. http://dx.doi.org/10.1007/BF01867550

Brooks, R. P., J. P. Hepp, and J. B. Hill. 1987. Wetland creation opportunities on coal mined lands. p. 181-184. In J. Zelazny and J. S.

Feierabend (eds.), Increasing our wetland resources. Proc. of a Conf., Natl. Wildl. Fed., Washington, DC.

Cairns, J., Jr. 1985. Keynote address: facing some awkward questions concerning rehabilitation management practices on mined lands. p. 9-17. In R. P. Brooks, D. E. Samuel, and J. B. Hill (eds.), Wetlands and water management on mined lands. Proc. of a Conf., PA State Univ., University Park, PA.

Cairns, J. Jr., and J. R. Pratt. 1985. Aquatic environments on mined lands: progress and future needs. p. 1-8. In R. P. Brooks, D. E. Samuel, and J. B. Hill (eds.), Wetlands and water management on mined lands. Proc. of a Conf., PA State Univ., University Park, PA.

Daubenmire, R. F. 1970. Steppe vegetation of Washington. WA Agric. Exp. Stat. Tech. Bull. 62.

Garbisch, E. W. 1989. Wetland enhancement, restoration, and construction. p. 261-275. In S. K. Majumdar, R. P. Brooks, F. J. Brenner, and R. W. Tiner, Jr. (eds.), Wetlands ecology and conservation: Emphasis in Pennsylvania. PA Acad. Sci., Easton, PA.

Hedin, R. S. 1989. Treatment of coal mine drainage with constructed wetlands. p. 349-362. In S. K. Majumdar, R. P. Brooks, F. J. Brenner, and R. W. Tiner, Jr. (eds.), Wetlands ecology and conservation: emphasis in Pennsylvania. PA Acad. Sci., Easton, PA.

Kadlec, R. H. 1989. Wetlands for treatment of municipal wastewater. p. 300-314. In S. K. Majumdar, R. P. Brooks, F. J. Brenner, and R. W. Tiner, Jr. (eds.), Wetlands ecology and conservation: emphasis in Pennsylvania. PA Acad. Sci., Easton, PA.

Kusler, J. A. 1990. Views on scientific issues relating to the restoration and creation of wetlands. p. 217-230. In G. Bingham, E. H. Clark II, L. V. Haygood, and M. Leslie (eds.), Issues in wetlands protection: background papers prepared for the National Wetlands Policy forum. The Conservation Foundation, Washington, DC.

Kusler, J. A., and M. E. Kentula. 1990. Executive summary. p. xvii-xxv. In J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. Island Press, Washington, DC.

Lacki, M. J, J. W. Hummer, and H. J. Webster. 1991a. Effect of reclamation technique on mammal communities inhabiting wetlands on mined lands in east-central Ohio. OH J. Sci. 91(4):154-158.

Lacki, M. J., J. W. Hummer, and H. J. Webster. 1991b. Mine-drainage treatment wetland as habitat for herptofaunal wildlife. Environmental Management 16(4):513-520. http://dx.doi.org/10.1007/BF02394127

Lacki, M. J., J. W. Hummer, and H. J. Webster. 1991c. Avian diversity patterns at a constructed wetland: use of ecological theory in the evaluation of a mine land reclamation technique. Int. J. Surface Min. and Reclam. 5(1991):101-105. http://dx.doi.org/10.1080/09208119108944293

Mitsch, W. J., and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Co. Inc., New York. 539p.

Niering, W. A. 1987. Vegetation dynamics (succession and climax) in relation to plant community management. Conservation Biology 1(4):287-295. http://dx.doi.org/10.1111/j.1523-1739.1987.tb00049.x

Niering, W. A. 1989. Wetland vegetation development. p. 103-113. In S. K. Majumdar, R. P. Brooks, F. J. Brenner, and R. W. Tiner, Jr. (eds.), Wetlands ecology and conservation: emphasis in Pennsylvania. PA Acad. Sci., Easton, PA.

Niering, W. A. 1990. Vegetation dynamics in relation to wetland creation. p. 479-486. In J. A. Jusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. Island Press, Washington, DC.

Odum, E. P. 1971. Fundamentals of ecology. W. B. Saunders Co., Philadelphia, PA.

Odum, W. E. 1987. Predicting ecosystem development following creation and restoration of wetlands. p. 67-70. In J. Zelazny and J. S. Feierabend (eds.), Increasing our wetland resources. Proc of a Conf., Natl. Wildl. Fed., Washington, DC.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry: the principles and practices of statistics in biological research. W. H. Freeman and Co., San Francisco, CA. 776 p.

Stark, L. R., R. L. Kolbash, H. J. Webster, S. E. Stevens, Jr., K. A. Dionis, and E. R. Murphy. 1988. The Simco #4 wetland: patterns and performance of a wetland receiving mine drainage. p. 332-344. In Mine drainage and surface mine reclamation. Vol. I: Mine water and mine waste. Bu Mines IC 9183, Pittsburgh, PA. http://dx.doi.org/10.21000/JASMR88010332

Stark, L. R., S. E. Stevens, Jr., H. J. Webster, and W. R. Wenrick. 1990. Iron loading, efficiency and sizing in a constructed wetland receiving mine drainage. p. 393-401. In Proc. of the 1990 Mining and Reclamation Conf. and Exhibition. 2 Vols. WV Univ., Morgantown, WV.
http://dx.doi.org/10.21000/JASMR90020393

Steenis, J. H., L. P. Smith, and H. P. Cofer. 1959. Studies on cattail management in the Northeast. Trans NE Wildl. Conf. 10:149-155.

Wieder, R. K. 1989. A survey of constructed wetlands for acid coal mine drainage treatment in the eastern United States. Wetlands 9(2):299-315.
http://dx.doi.org/10.1007/BF03160750

Wyngaard, G. A. 1985. Ethical and ecological concerns in land reclamation policy: an analysis of the Surface Mining Control and Reclamation Act of 1977. p. 75-81. In R. P. Brooks, D. E. Samuel, and J. B. Hill (eds.), Wetlands and water management on mined lands. Proc. of a Conf., PA State Univ., University Park, PA.