DIVERSITY PATTERNS OF INVERTEBRATE FAUNA IN CATTAIL WETLANDS RECEIVING ACID MINE DRAINAGE[1]

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Abstract. Invertebrate diversity patterns at a three-celled, 0.3 ha, cattail wetland, constructed in 1985 to receive mine drainage, were surveyed during May and June in 1988 and 1989. Three nearby sites, each comprised of three volunteer cattail cells, were also examined. Benthic invertebrates were collected using an Ekman dredge and volant insects were obtained with sticky traps covered with tangle-trap. Dredge samples were examined at the family level and sticky trap samples at the ordinal level.

Substrates from the constructed wetland contained significantly fewer taxonomic families and total numbers of invertebrates than the other sites. Shannon-Weaver diversity indices (H') also demonstrated that the constructed wetland supported a simple community relative to the other sites; however, the number of invertebrate families in the constructed wetland increased from three in 1988 to eight in 1989. Dipteran larvae were the most abundant invertebrates in the sediments from the constructed wetland.

The constructed wetland supported significantly higher numbers of volant insects than the other sites, but no difference in the number of taxonomic orders was found across sites. Shannon-Weaver diversity indices showed the constructed wetland to be intermediate in ordinal diversity relative to the other sites, with these values influenced by a site by year interaction effect. The number of orders of insects recorded in sticky trap samples at the constructed wetland increased from seven in 1988 to nine in 1989. The implications of these findings for assessing the overall value of surface mine wetlands are discussed.

Additional key words: Aquatic invertebrates, diversity indices, surface mine wetlands.

Introduction

The construction of wetlands to treat acid mine drainage is a practice that is receiving increased acceptance (Girts and Kleinmann 1986), as these systems require limited maintenance and are more cost effective than the continued application of chemicals. Research examining the functional efficiency of constructed wetlands for removal of iron and manganese, along with the elevation of water pH level, has been conducted (Stark et al. 1988, Stillings et al. 1988), but a complete evaluation of the environmental integrity of these wetlands requires an examination of the biotic components that are contained within these systems.

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The use of food chain support in assessing a wetland's potential for sustaining fish and wildlife populations is arguably a valid approach (Harris 1988), as a wetland will function depending upon its proximity to other wetlands and terrestrial input sources in the surrounding landscape (Klopatek 1988). However, if constructed wetlands are to function as ecological equivalents of natural wetlands, then all system processes, including food chain support, should be established. Klopatek (1988) indicated that wetland food chains begin with autotrophs or detritus. A plant base (autotrophs) is normally provided in constructed wetlands, with the detrital component left to develop over time. The implications of this approach for aquatic invertebrates inhabiting the benthic zone of constructed wetlands have not been resolved. Benthic invertebrate communities are dependent on the supply of detritus, and thus represent an integral component of detritus-based food chains in wetland systems.

Studies examining invertebrate taxa in surface-mine waters have emphasized lakes and ponds that were mostly alkaline in pH and generally supportive of diverse biotic communities (Hepp 1987, Fowler et al. 1985, Jones et al. 1985). Wetlands constructed in the headwaters of stream drainages (lotic systems), designed primarily to filter water containing acid mine runoff, have not been examined for benthic invertebrates. Bosserman and Hill (1985) showed that populations of benthic invertebrates in natural stream headwaters were negatively impacted when exposed to drainage inputs from surface mines, suggesting that benthic invertebrates inhabiting wetlands constructed to treat surface mine runoff may exhibit similar stress responses.

A thorough evaluation of any constructed wetland requires an examination of the biotic communities contained therein, and an assessment of impacts upon the biota downstream. Pinder and Farr (1987) indicated, with some exceptions, that diversity of aquatic organisms declined under exposure to environmental stress. We present results from an ongoing study examining diversity patterns of benthic invertebrates and volant insects occupying a constructed, cattail (Typha latifolia) wetland in relation to natural cattail wetlands both downstream and within the surrounding watershed. This paper represents one phase of a long-term study evaluating the diversity patterns of organisms at all levels of the food chain in the constructed wetland.

Materials and Methods

Four sites were selected for study. All sites were located within the Wills Creek drainage system, in Coshocton and Muskingum Counties, Ohio. A history and description of the constructed wetland (Simco #4) is presented in Stark et al. (1988). The remaining three sites were each composed of three cattail cells to allow direct comparison with the design of the Simco #4 wetland. One site was located directly downstream (Downstream) from the constructed wetland. This site had been slightly disturbed by the presence of a power line right-of-way neighboring the output end of the third cattail cell, and by historical mining activity throughout the surrounding hillsides. Mining activity ceased in the vicinity of the Downstream site as of 1961 (T. Romanoski, pers. commun.). The third site (Volunteer) represented a drainage system with minimal disturbance from mining activity, whereas the final site (Reclamation) represented a reclaimed strip mine with volunteer cattail wetlands present in the drainage bottom.

Samples for benthic invertebrates and volant insects were collected during four sampling periods: 19 to 25 May, 1988; 10 to 15 June, 1988; 22 to 26 May, 1989; and 12 to 16 June, 1989. Benthic invertebrates were obtained using an Ekman dredge sampler, with five samples collected randomly from each cattail cell by site combination during each sampling period. Macroinvertebrates were extracted from each substrate sample and identified to family using a binocular microscope. Volant insects were captured using 0.18 square meter-sticky traps suspended approximately 0.75 m aboveground. White (color) traps were covered with tangle-trap adhesive on each side. Two traps were established at the midpoint of each cattail cell and run for two nights during each sampling period. Insects were identified to order using a binocular microscope and were enumerated. The Shannon-Weaver diversity index (H') was derived for all faunal samples, with data grouped by cattail cell. A discussion of this computational method is provided in Hair (1980). The value in using a diversity index over biotic indices to assess stress responses of invertebrates in wetland systems is that they do not assume any tolerance level for a particular species group to a given pollutant (Pinder and Farr 1987).

Water quality was assessed by collecting replicate samples from the inflow to each cattail cell, and the outflow of the cattail cell furthest downstream at a site. One sample was acidified for metal analysis with nitric acid, while the other sample remained untreated and was analyzed for remaining properties. Samples were iced, delivered to the Central Environmental Services testing facility (Clearfield, PA 16830),

Table 1.--Numbers of macroinvertebrates recorded in benthic samples across wetlands sampled, 1988 and 1989 combined.

Taxonomic order	Common name	No. Families	No. Collected Simco	Downs	Volun	Recla
Molluscs						
Heterodonta	bivalves	1	-	306	472	758
Basommatophora	pulmonate snails	3	-	432	87	46
Stylommatophora	gilled snails	1	-	-	8	1
Crustaceans						
Cyclopoida	copepods	1	1	347	179	111
Decapoda	crayfish, shrimp	2	-	-	1	109
Isopoda	sowbugs	1	-	-	2	-
Insects						
Diptera	flies	9	59	153	118	122
Neuroptera	alderflies	1	-	10	56	12
Coleoptera	beetles	5	2	6	24	10
Trichoptera	caddisflies	2	-	29	-	6
Odonata	dragonflies	1	2	1	-	-
Collembola	springtails	1	-	1	-	-
Homoptera	aphids	1	1	-	-	-

and analyzed for iron, manganese, pH value, acidity, and alkalinity. Samples were collected on 10 August in both 1988 and 1989.

All data were analyzed using a balanced, nested analysis of variance (SAS Institute 1982). ANOVA's were treated as mixed effects models, with sites as fixed, main effects. The random effect varied among tests depending on the data collection procedure. For all tests of faunal data cattail cells were used as the random effect. Sample location was used as the random effect for tests of water quality because samples were acquired between, and not within, cattail cells. Subsequently, cattail cell mean square and sample location mean square were used as the error terms for testing site effects. Where appropriate, the month and year of sampling were used as block effects and evaluated for possible interactions with site effects. For all models where significant site effects were obtained, site means were tested using Tukey's studentized range test. Test outcomes were considered significantly different when a $P < 0.05$ was achieved. Data for number of benthic invertebrates and iron content were both log transformed prior to analysis to surmount the problem of unequal variances across site (main effect) means.

Results and Discussion

Insect larvae represented the majority of taxonomic families of macroinvertebrates found in the dredge samples (Table 1). Dipterans (flies) were the most abundant group in the benthos of the constructed wetland with six families present. Of these, the Chironomidae were most common representing 76.3% (n = 45) of the number of dipteran larvae found. All

Table 2.--Total numbers per sample (N), number of families per sample (F) and diversity patterns (H') of benthic invertebrates across wetlands sampled, 1988 and 1989 combined.

Sites	No. Samples	N Mean	N s.d.	F Mean	F s.d.	H' Mean	H' s.d.
Simco #4	60	5.42[b]	7.15	1.33[b]	1.37	0.31[b]	0.50
Downstream	60	107.9[a]	86.3	6.17[a]	1.95	1.11[a]	0.42
Volunteer	60	80.2[a]	59.6	6.67[a]	2.10	1.13[a]	0.38
Reclamation	60	98.1[a]	96.4	7.08[a]	1.08	1.13[a]	0.47

[a,b]Within columns, means without common letters are significantly different at P = 0.05. Data for N were log transformed prior to analysis.

Table 3.--Numbers of invertebrates recorded in sticky trap samples across wetlands sampled, 1988 and 1989 combined.

		No. Collected				%
Taxonomic order	Common name	Simco	Downs	Volun	Recla	Total
Diptera	flies	3537	2521	2377	1658	82
Coleoptera	beetles	385	332	250	323	11
Homoptera	aphids, leaf hoppers	69	41	51	78	3
Hymenoptera	bees, wasps	63	57	21	29	1
Hemiptera	bugs	18	62	14	25	1
Lepidoptera	butterflies, moths	20	15	18	30	*
Araneida	spiders	16	16	13	13	*
Neuroptera	alderflies	3	6	7	20	*
Orthoptera	crickets, grasshoppers	2	1	2	2	*
Odonata	dragon & damselflies	1	2	1	-	*
Trichoptera	caddisflies	-	1	-	1	*
Ephemeroptera	mayflies	-	-	1	-	*

* = less than 1%.

of these were recorded in the 1988 sampling effort. The constructed wetland was completely lacking in bivalves (clams) and snails, and exhibited a paucity of crustaceans, with only one copepod present across the two years sampled.

The remaining three wetlands were much richer in both numbers and families of benthic invertebrates than Simco #4 (Tables 1 and 2), yielding significantly greater values for diversity (H'). No significant month or year effects were obtained for numbers, families, or diversity of benthic invertebrates. The Downstream, Volunteer, and Reclamation sites appeared to support benthic communities that were more stable than those for the Simco #4 site. In the former case, the number of taxonomic families found at a site during a particular year ranged from 14 to 16, whereas at Simco #4 the number increased from three in 1988 to eight in 1989. Further, the number of families found to occur in common to both years of collecting at a site ranged from eight to 11 for the natural wetlands, while only one family (Libellulidae - dragonfly larvae) was found to occur in Simco #4 during both years sampled.

Dipterans were the most frequently captured invertebrate in sticky trap samples across all four sites (Table 3). With the exception of a small number of spiders (Araneida), volant insects made up all of the specimens collected on sticky traps. The abundance of insect orders did not differ across sites and remained stable between sampling years. Simco #4 increased in the abundance of insect orders from seven to nine, whereas the Downstream site decreased from nine to seven. Simco #4 exhibited significantly higher numbers of volant insects in sticky

Table 4.--Total numbers per sample (N), number of orders per sample (O), and diversity patterns (H') of volant insects across wetlands sampled, 1988 and 1989 combined.

	No.	N		O		H'	
Sites	Samples	Mean	s.d.	Mean	s.d.	Mean	s.d.
Simco #4	24	343[a]	140.8	5.92	1.31	0.58[a,b]	0.20
Downstream	24	254[a,b]	89.0	6.58	0.90	0.66[a,b]	0.20
Volunteer	24	230[b]	69.6	6.25	1.06	0.54[b]	0.17
Reclamation	24	182[b]	45.4	6.25	1.48	0.78[a]	0.21

[a,b]Within columns, means without common letters are significantly different at P = 0.05.

trap samples than either the Volunteer or Reclamation site and was intermediate in ordinal diversity (Table 4). The significantly higher numbers were due primarily to the abundance of dipterans collected (Table 3). This significantly higher abundance of adult flies at Simco #4 may at first be partially explained by the dominance of fly larvae in the dredge samples for this site (Table 1); however, given the overall lower abundance of benthic invertebrates at Simco #4 relative to the natural wetlands, this explanation is unlikely.

A significant year by site interaction effect ($P < 0.03$) was obtained for the analyses of ordinal diversity (H'). This outcome was difficult to interpret as mean diversity levels for the Simco #4 and Downstream sites did not vary between years, while the Volunteer and Reclamation sites declined in mean value from 1988 to 1989 (Table 5). Why such a difference would occur among the sites examined is unclear, but it may be tied to the substantially different rainfall patterns that resulted in 1988 and 1989, as a severe drought took place during the growing season of 1988.

Metal analysis showed no differences for manganese across all four sites examined (Table 6). Levels of iron in the water at the Downstream site were not significantly different from the remaining natural wetlands, indicating that the constructed wetland was removing substantial amounts of iron because iron levels in Simco #4 were significantly higher than all other sites (Table 6).

Mean pH values increased significantly ($P < 0.0001$) across all sites from 1988 to 1989. Simco #4 had significantly lower pH values than the three natural wetlands (Table 6), with this pattern paralleled by mean acidity levels, as Simco #4 had significantly higher levels of acidity than the remaining sites. A significant year by site interaction effect ($P < 0.004$) was obtained for mean acidity levels, but an examination of the means across years revealed no interpretable pattern. Levels of alkalinity in Simco #4 were intermediate to those for the other sites, with the Reclamation site exhibiting significantly higher levels than the remaining three sites (Table 6). A significant year by site interaction effect ($P < 0.0001$) was also found for alkalinity, with the Downstream, Volunteer, and Reclamation sites all showing large declines from 1988 to 1989.

The constructed wetland (Simco #4) supported a much simpler and relatively unstable benthic community than natural wetlands in the surrounding watershed. Whether these differences were due to higher acidity levels, higher levels of iron, synergistic effects of the two aforementioned factors, or to an insufficient time for benthic communities to develop is uncertain. Eilers et al. (1984) compiled a literature review that demonstrated tolerance of pH levels by a variety of macroinvertebrates equal to and below pH levels recorded at Simco #4. The dominance by dipterans, particularly chironomids, in samples from Simco #4 coincided with a study examining impacts of acid mine drainage on stream biota that showed the most heavily impacted streams to have simpler benthic communities comprised primarily of chironomids (Bosserman and Hill 1985). Hepp (1987) examined newly created surface-mine wetlands not impacted by acid drainage and also found chironomids to be the most frequent colonizer in the benthos of these systems.

In terms of diversity (H') and overall richness of macroinvertebrates, the Downstream site appeared to be functioning in a manner compatible with the other natural wetlands examined. This suggested that the Simco #4 wetland was ameliorating probable negative impacts from acid drainage on the benthic fauna directly downstream from the point source. Water chemistry analyses supported this conclusion, indicating that water quality at the Downstream site was comparable to that for the Volunteer and Reclamation sites.

Larson (1988) has pointed out that achieving acceptable standards for wetland construction might be contingent on allowing sufficient time for some essential ecosystem components to develop naturally after a wetland is established

Table 5.--Mean ordinal diversity levels (H') for volant insects by year across wetlands sampled.

	Simco #4		Downstream		Volunteer		Reclamation	
Year	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
1988	0.55	0.21	0.64	0.16	0.65	0.12	0.92	0.17
1989	0.60	0.21	0.68	0.25	0.44	0.15	0.64	0.14

Table 6.--Water quality parameters for wetlands examined. Except for pH value, all units are in mg/liter. Sample size equals 4 in all cases.

		pH		Fe		Mn		Acidity		Alkalinity	
Site	Year	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Simco	1988	5.92[b]	0.06	75.3[a]	46.9	1.93	0.08	28.8[a]	27.4	102[b]	42.2
	1989	6.26	0.05	52.8	24.7	1.48	0.06	18.6	24.8	104	36.2
Downs	1988	6.59[a]	0.25	0.84[b]	0.95	0.52	0.27	-22.4[b]	6.06	62.5[b]	7.11
	1989	6.76	0.12	0.56	0.08	0.64	0.05	-26.4	2.01	46.1	1.89
Volum	1988	6.88[a]	0.15	2.74[b]	2.98	3.83	2.83	-52.2[b]	8.19	106[b]	2.96
	1989	7.12	0.10	2.53	3.15	2.57	1.48	-44.6	3.35	73.8	4.80
Recla	1988	6.96[a]	0.42	0.97[b]	0.76	3.54	2.20	-127[c]	32.4	200[a]	28.2
	1989	7.18	0.54	5.71	10.5	1.90	1.70	-121	35.4	156	35.9

[a,b,c]Within columns, means without common letters are significantly different at P = 0.05. Tests based on the overall means for a site with years combined. Data for Fe were log transformed prior to analysis.

(i.e., a time lag effect). Data for Simco #4 indicate that aquatic macroinvertebrates were poorly represented in the benthos, but adult, volant insect communities were comparable to nearby natural wetlands. Adult insects are more mobile than aquatic macroinvertebrates and were able to colonize the available habitat at Simco #4 more quickly. The rate at which a constructed wetland achieves a complete faunal composition is likely to be a function of its juxtaposition to other wetlands nearby (Klopatek 1988). However, where wetlands are implemented to ameliorate environmental disturbance, achievement of the equivalent to naturally functioning systems may take a longer period of time or may not be possible at all. In the latter case, prevention of negative impacts downstream from constructed wetlands would still justify their implementation, especially if partial wetland benefits were accrued in the vicinity of the wetland without creating an additional environmental hazard through bioaccumulation of metals in the tissues of vertebrate animals at higher levels in the food chain. Iron and manganese levels are presently being examined in tissues of vertebrates inhabiting the Simco #4 wetland and vicinity.

No data exist to indicate whether modifications to wetland design could hasten the development of a complex, benthic invertebrate community. In the particular case of riparian, headwater wetlands, modifications in shoreline terrestrial vegetation to provide shading effects and allocthonous inputs of woody debris may facilitate the establishment of some benthic species through creation of more suitable habitat conditions (Vannote et al. 1980, Minshall et al. 1985).

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