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Natural succession of benthic populations in constructed sediment ponds and ditches in southwestern West Virginia

Robin E. Dolin

Natural succession of benthic populations in constructed sediment ponds and ditches in southwestern West Virginia

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Robin E. Dolin

Marshall University

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Advisor Dr. Donald Forth

Department of Biological Sciences

[signature]
Dean of the Graduate College

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This thesis, and all the effort behind it, is
dedicated in loving memory of my father,

David R. Dolin

from your little fishing buddy

Abstract

Strip mining causes major disturbances of the natural environment. One such disturbance is the creation of valley fills, which often fill in the headwaters of small streams. Runoff from these valley fills can cause heavy siltation as well as acid and heavy metal deposition downstream. One way to combat this problem is through the construction of sedimentation ponds, which slow down the flow of water so that sediment can settle out and water chemistry can be altered before the water is discharged into the stream. Since these ponds are, in effect, temporarily replacing small headwaters once present, the question is raised as to whether or not ponds support a healthy benthic macroinvertebrate community and if these ponds are undergoing succession. In this study, two separate pond systems were examined. First, two ponds that were first assessed by EPA Rapid Bioassessment Protocols in 1997 were reexamined in 2000 to determine whether or not there was a noticeable change in metrics. Taxa richness did not change for either pond from 1997 to 2000, remaining at 11 taxa present for Rollem Fork #2 and 16 taxa present for Vance Branch. Mostly members of the orders Diptera, Ephemeroptera, and Odonata represented the benthic community in the ponds. These taxa contained an abundance of tolerant members with a few facultative ones, and in the case of Vance Branch in 1997, two species of sensitive Ephemeroptera (*Stenacron* and *Leptophlebia*) that were lost in the 2000 sampling season. The modified Hilsenhoff Biotic Index and Shannon Diversity indicated that the ponds were moderately to severely disturbed in both sampling years. The percent contribution of the dominant taxon was high for both ponds in

1997 and 2000. Furthermore, dominant taxa for Rollem Fork, Oligochaete in 1997 and Chironomidae in 2000, are considered tolerant. Chironomidae, a tolerant family, dominated Vance Branch in both years. The ratio of scraper and filtering collector functional feeding groups, ratio of EPT and Chironomidae abundances, EPT index, ratio of shredder functional feeding group and total individuals, and evenness values also pointed to an unbalanced, perturbated system. Overall results in 2000 indicated that there was little difference between the benthic populations in 1997 and 2000. Additionally, the protocols point toward two moderately to severely polluted systems. However, the validity of using Rapid Bioassessment Protocols, meant for running waters, to analyze lentic environments is questioned and alternative methods for these environments are proposed. The second study, a seasonal assessment of three ponds of different ages draining the same valley fill, gave unexpected results. Again, the ponds were dominated by taxa from the orders Diptera, Ephemeroptera, and Odonata. However, a different method of assessing succession in the ponds in the seasonal study was used. These ponds were compared to an older sediment pond that is no longer impacted by mining by using STATISTICA Cluster Analysis. It was discovered that the youngest pond, WB3, was actually the least dissimilar, or most similar, to the reference pond (HBREF) in all seasons. There was also no clear evidence that the younger experimental ponds, WB3 and WB4, are becoming more like the older experimental pond, WB5. Other studies have indicated that constructed temporary ponds are likely to host a limited variety of taxa and that after a period of colonization, those taxa do not change much. It is possible that the ponds in the seasonal study are different enough in habitat, chemistry, and benthic composition, that it is impossible to base their individual succession on comparison with other ponds.

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Introduction

Surface mining of coal involves removing overlying soil and rock in order to expose the seam of coal. This extensive disturbance of land can create severe environmental problems. In some types of surface mining, overburden is disposed of into nearby valleys, which typically contain headwaters for small streams. A critical feature of strip-mine ecology is the massive erosion and subsequent sedimentation in these streams. The procedure for reducing the amount of acid and sediment flowing downstream in a valley fill, as set forth by section 515 of the Surface Mining Control and Reclamation Act of 1977, is for the construction of a sedimentation pond. By slowing the flow of water at the base of the valley fill, sediment will settle out and not flow downstream. Also, the ponds are treated with an agent that stabilizes pH. In general, all parties involved understand the need for controlled operation and reclamation of the mined lands. Coal companies see their use of the land as temporary and claim that reclamation benefits landowners and communities by providing new uses for the land. However, the study of the long-term effects of mining and reclamation on an area, particularly a watershed and its inhabitants, warrants further research.

One coal company in West Virginia has found that a series of sediment ponds is more effective than one large pond in the removal of acid and sediment from the waterway. The West Virginia Division of Environmental Protection enforces the regulation that, before bond release on reclamation, sedimentation ponds must be removed and the stream returned to as close to its original contour as possible. However, while these temporary ponds are in existence, animal and plant communities utilize them for habitat. Gee et al. (1997) found that plants and invertebrates were the first to colonize new pond communities. The composition of these communities, in the case of this study, communities of benthic macroinvertebrates, can give some insight into the quality of the ponds and whether they are undergoing succession, that is, moving from a community of more pollution tolerant taxa to more pollution-sensitive taxa.

The purpose of this study was to determine whether ponds of different ages draining the same valley fill are exhibiting benthic macroinvertebrate succession from season to season within the ponds and from season to season among the ponds. Also, another investigation that replicates a study by an independent environmental consulting firm in 1997 will reveal whether two other ponds draining a different valley fill show any successional changes among benthic macroinvertebrates.

Materials and Methods

Study Site

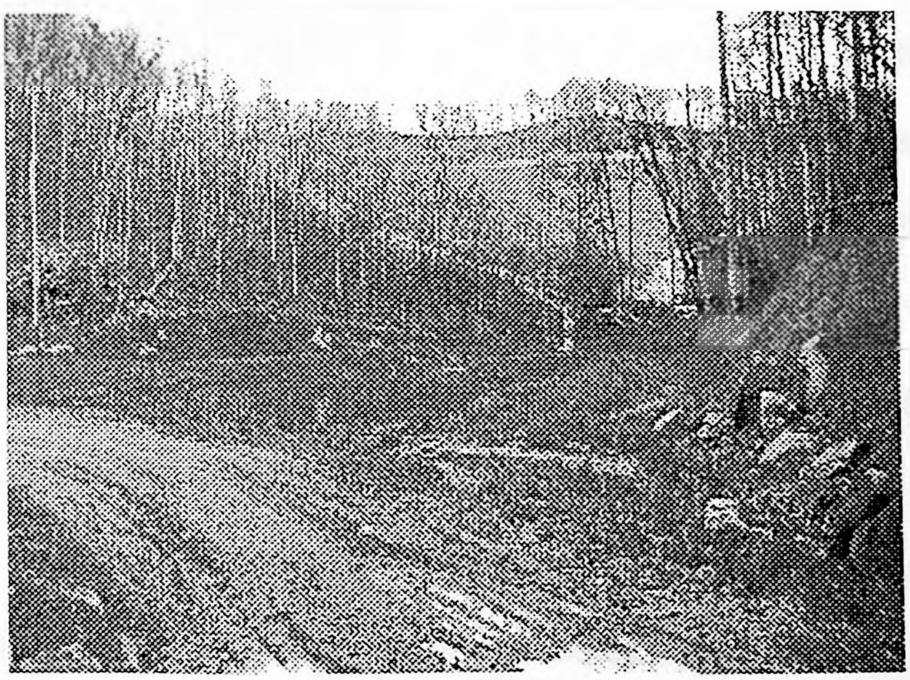
Six sedimentation ponds, belonging to one coal company, were chosen for this study. All of the ponds were located near Dunlow, in southern Wayne County, West Virginia. Wayne County lies in the unglaciated Allegheny Plateau Section of the Appalachian Plateau Physiographic Province of West Virginia (Fenneman, 1950). Shales, sandstones, and smaller amounts of limestone primarily underlie this area (Mills and Delcourt, 1991). Surface rocks in this area are sedimentary and consist primarily of sandstone, siltstone, shale, thin limestones, and coal of the Pennsylvania age (Soil Conservation Service, 1961). Mining activity is expected to impact approximately 146 acres of the watershed that contains the seasonal study site. Previously, the entire area was used as wildlife habitat and for other natural resources development. It has gone undeveloped commercially or residentially. The second study, which involved a one-time sample, included one pond from the seasonal study site and two ponds from another watershed. A reference sample was collected from a third watershed.

Field Collections

The one-time study was done to duplicate a study performed by an independent consulting firm in 1997 (REIC, 1997). Two ponds from the same watershed, Rollem Fork #2 and Vance Branch, were used in this study. Hester-Dendy multiplate samplers and gravel baskets, both designed to mimic natural benthic macroinvertebrate substrate, were attached to cinderblocks and placed in the ponds 5-6 meters from the shore. The samplers were allowed to stay in place for one month at which time they were collected and preserved in 70% ethanol to be transported back to the lab. At the same time that the samplers were retrieved, 1m^2 kick-net samples were also taken at the inflow and outflow of the ponds. For this study, all insects collected were separated from debris and enumerated to the lowest practical taxon. All insects collected were identified in order to maintain consistency between this study and the study performed in 1997.

A seasonal study site was also visited at least twice a season in Fall 1999, Winter 1999/2000, Spring 2000, and Fall 2000. Three ponds located in the same watershed were used in the seasonal study. Wiley Branch #5 (WB5) was the oldest pond at approximately 3 years at the beginning of the study. Wiley Branch #4 (WB4) was approximately 1 year old and Wiley Branch 3 (WB3) was approximately 4 months old at the beginning of the study. Dredge samples were taken in a 1m^2 area at both the inlet and outlet of the pond. Water samples were taken and sent to an independent laboratory for analysis. A 1m^2 structure was constructed from PVC pipe in the lab and a standard D-shaped dredge was used to sample within the boundaries of the structure. Insects and debris caught in the net were immediately preserved in 70% ethanol and transported back to the laboratory where the insects were separated from the debris and enumerated to the lowest practical taxon using standard EPA subsampling techniques (USEPA, 1999).

A reference sample was taken from Honey Branch, a 10-year-old pond from a third watershed. The purpose of the reference sample was to compare its insect population to those of the seasonal ponds to determine how unlike or alike the seasonal ponds are to the reference pond. Insects were separated from the debris and enumerated to the lowest practical taxon using standard EPA subsampling techniques (USEPA, 1999).



Wiley Branch pond #4 with a valley fill in the background

Data Analysis

One-Time Study

In order to maintain consistency between the investigations done in 1997 and the one performed in this study, the following EPA Rapid Bioassessment protocols were utilized to analyze the collected data (USEPA, 1989).

Metric 1. Species richness – This reflects the health of the community through a measurement of the variety of taxa, or total number of taxa, present in the sample. Generally, species richness increases with increasing water quality, habitat diversity, and/or habitat sustainability.

Metric 2. Modified Hilsenhoff Biotic Index – This index was developed by Hilsenhoff to summarize overall pollution tolerance of the benthic arthropod community with a single value. Tolerance values range from 0 to 10, increasing as water quality decreases. The formula used for calculating the biotic index is $HBI = \Sigma x_i t_i / n$ where x_i = number of individuals within a species, t_i = tolerance value of a species, and n = total number of organisms in the sample. Tolerance values for each genus can be found in *USEPA Rapid Bioassessment Protocols For Use In Streams And Rivers,* 1999.

Metric 3. Ratio of Scraper and Filtering Collector Functional Feeding Groups – The scraper and filtering collector functional group ratio reflects the riffle/run community foodbase. In this environment, it provides insight into the nature of potential disturbance factors. The predominance of a particular feeding group may indicate an unbalanced community that is responding to an overabundance of a particular food type. Functional feeding group classifications can be found in Merritt and Cummins (1996).

Metric 4. Ratio of EPT and Chironomidae Abundances – This metric uses the relative abundance of EPT (Ephemeroptera, Plecoptera, Trichoptera) and Chironomidae indicator groups as a measure of community balance. A community is considered to be in good biotic condition in relation to this metric if there is a relatively even distribution among all four groups. The EPT groups are considered to be more pollution sensitive and a substantial representation by these groups is desirable. Populations with a disproportionately high number of chironomids, which are considered generally pollution tolerant, may be experiencing environmental stress. Chironomids generally become more dominant along a gradient of increasing enrichment or heavy metals concentration.

Metric 5. Percent Contribution of Dominant Taxon – This is a measure of the overall abundance of the dominant taxon in relation to the total number of organisms present in the community. A community dominated by relatively few or pollution tolerant organisms indicates environmental stress.

Metric 6. EPT Index – This index generally increases with increasing water quality. The EPT index is a measure of the total number of distinct taxa within the orders of Ephemeroptera, Plecoptera, and Trichoptera. Members of these particular taxa are generally considered to be more pollution sensitive.

Metric 7. Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected – This ratio is also based on the functional feeding group concept and can also indicate environmental stress as indicated by the CPOM (Coarse Particulate Organic Matter)-based Shredder community. Shredders are sensitive to riparian zone impacts and can indicate toxic effects when the toxicants are absorbed directly by the CPOM.

Metric 8. Shannon Diversity – The Shannon Diversity was originally not included in the 1997 study, but was calculated for both investigations because of its ability to indicate environmental stress by measuring taxa diversity. It was calculated using the Ecological Analysis software package. With the Shannon Diversity, communities can fall into one of three pollution categories based on a score:

3-4: indicates a relatively unpolluted system

2-3: indicates a moderately polluted system

<1: indicates a severely polluted system

Metric 9. Evenness – This metric, also calculated using the Ecological Analysis software package, was not included in the original 1997 investigation. Again, it was included in my study because it simply looks at how evenly the represented taxa in the community are distributed and is applicable to pond communities as well as riffle/run communities. A more evenly distributed community indicates a more stable environment. Evenness values range from 0 to 1, with a higher value indicating a more evenly distributed community.

Seasonal Study

While EPA Rapid Bioassessment Protocols were used in the one-time study in order to simply maintain consistency and comparability between the 1997 and 2000 investigations, a more effective tool was sought to analyze the community structures of the ponds used in the seasonal study. The purpose of this study was to see if, as the ponds grew older, their benthic community more closely resembled that of the 10-year-old reference site. In order to do this, a measure of community similarity is needed. Christman and Voshell (1993) used the Bray-Curtis community similarity index to measure the change in community structure in a pond over a two-year period. Originally this index was chosen to measure community similarity between the same seasons of the experimental ponds and the reference and among different seasons in the same pond and the reference in this study. A multivariate analysis, Cluster Analysis, was used instead. Cluster Analysis is part of the STATISTICA software package and instead of measuring the percentage of community similarity; it can measure the percentage of community dissimilarity. It indicates how dissimilar each pond is to the reference pond and to the other experimental ponds in the study. The less dissimilar the pond is to another pond, the more their community structures are alike. If ponds are undergoing successional change, they should show a trend of becoming less dissimilar to the reference pond and, in the case of WB3 and WB4, the older experimental pond (WB5) as they age. Percent dissimilarity is expressed with a correlation matrix and graphically as a joining tree cluster.

Water Chemistry

Several water chemistry parameters were analyzed for each pond in order to determine the role of water chemistry in the composition of benthic communities. Field pH, total sulfates (mg/L), total aluminum (mg/L), total iron (mg/L), total suspended solids (mg/L), total dissolved oxygen (mg/L), and total conductivity (umhos/cm) were considered the most significant parameters. The concentrations of these parameters from each pond and each season were compared with the acceptable concentration limits for drinking water as set forth by the West Virginia Division of Environmental Protection Water Quality Board. However, some of the water chemistry data was incomplete. Samples were taken at each pond at every sampling period and were analyzed by Standard Laboratories, Inc. in South Charleston, West Virginia. This laboratory analyzes all water samples collected by the coal company. The water chemistry reports sometimes had incomplete or missing data because of either laboratory error or a particular parameter was not tested on that date, so all of the significant parameters could not be taken into account for every pond or every season.

Results

Benthos comparison in Rollem Fork #2 and Vance Branch, 1997 and 2000

EPA Rapid Bioassessment

Metric 1. Taxa Richness

Taxa richness did not change for either pond between 1997 and 2000. Eleven taxa were counted for each season in Rollem Fork #2 (Table 1) and sixteen were counted each season for Vance Branch (Table 2). The percent tolerant (T) taxa in Rollem Fork #2 decreased from 94.8% in 1997 to 94.4% in 2000 (Figs. 1, 2). No sensitive (S) taxa were observed in either year. For Vance Branch, the percent tolerant taxa increased slightly, from 86.1% to 86.4%. Also, in 1997, two sensitive taxa, *Stenacron* and *Leptophlebia*, were present but in 2000, these taxa were not observed in the community but were instead replaced by two unclassified (U) taxa, *Notonecta* and *Lestes* (Figs. 3, 4).

Metric 2. Modified Hilsenhoff Biotic Index

For both ponds, the Modified HBI change two-hundredths of a point between 1997 and 2000. The HBI decreased in Rollem Fork #2 from 5.93 to 5.91 and increased in Vance Branch from 5.67 to 5.69 (Table 3). These values indicate a moderately polluted system that is not changing although the numbers have shifted slightly.

Table 1. Abundances of benthic macroinvertebrates with tolerance values collected per sample from Rollem Fork #2 1997 and 2000. T=tolerant taxa, F=facultative taxa

Taxon	1997	2000	Taxon	1997	2000
Coleoptera			Odonata		
Hydrophilidae			Anisoptera		
Berosus (T)	0	1	Gomphidae		
Peltodytes (T)	0	13	*Gomphus* (T)	1	0
			Zygoptera		
			Coenagrionidae		
			Argia (T)	1	2
			Enallagma (F)	0	2
			Hesperagrion (T)	3	0
Diptera			Oligochaete (T)	311	4
Ceratopogonidae (T)	19	28			
Chironomidae (T)	288	672			
Tipulidae					
Dicranota (T)	1	0			
Ephemeroptera			Trichoptera		
Baetidae			Polycentropodidae		
Baetis (F)	14	0	*Cyrnellus* (F)	0	1
Caenidae					
Caenis (F)	0	21			
Ephemeridae					
Ephemera (F)	3	0			
Hexagenia (F)	1	4			
Hemiptera			Hirudinea		
Corixidae (T)	7	0	Glossiphoniidae (T)	0	1

Table 2. Abundance of benthic macroinvertebrates with tolerance values collected per sample from Vance Branch, 1997 and 2000. T=tolerant taxa, F=facultative taxa, S=sensitive taxa, U=unclassified taxa.

Taxon	1997	2000	Taxon	1997	2000
Coleoptera			Odonata		
Dytiscidae			Anisoptera		
Dytiscus (T)	0	56	Gomphidae		
Hydrophilidae			*Gomphus* (T)	1	0
Hydrochara (T)	0	2	*Hagenius* (T)	1	0
Hydrophilus (T)	0	1	Libellulidae		
Peltodytes (T)	0	1	*Erythemis* (F)	0	1
			Libellula (F)	0	1
			Plathemis (F)	0	1
Diptera			Zygoptera		
Ceratopogonidae (T)	46	23	Coenagrionidae		
Chironomidae (T)	1006	804	*Argia* (T)	4	0
Simulidae (T)	30	0	*Enallagma* (F)	0	21
Tipulidae			*Hesperagrion* (T)	12	0
Tipula (T)	2	0	Lestidae		
			Lestes (U)	0	4
Ephemeroptera			Trichoptera		
Baetidae			Hydropsychidae (F)	3	0
Baetis (F)	121	0			
Caenidae					
Caenis (F)	7	5			
Ephemerellidae					
Ephemerella (F)	9	0			
Heptageniidae					
Stenacron (S)	4	0			
Leptophlebiidae					
Leptophlebia (S)	1	0			
Siphlonuridae					
Siphlonurus (F)	0	108			
Hemiptera					
Corixidae (T)	40	23			
Notonectidae					
Notonecta (U)	0	2			

Fig. 1 Percent taxa according to tolerance value, Rollem Fork #2 1997

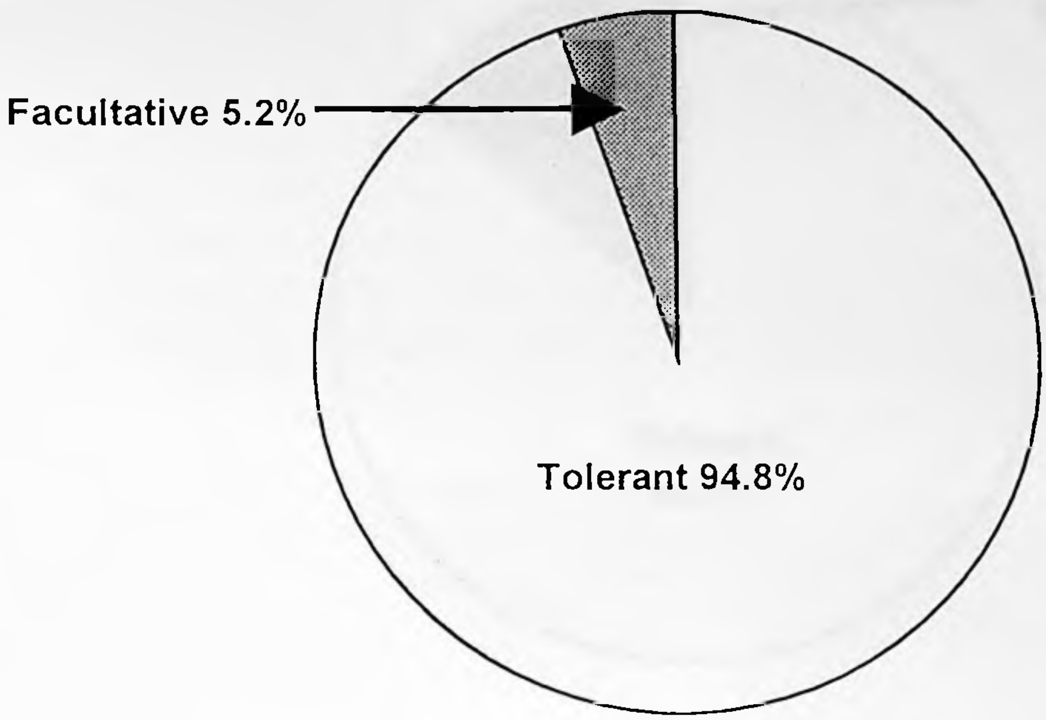


Fig. 2 Percent taxa according to tolerance value, Rollem Fork #2 2000

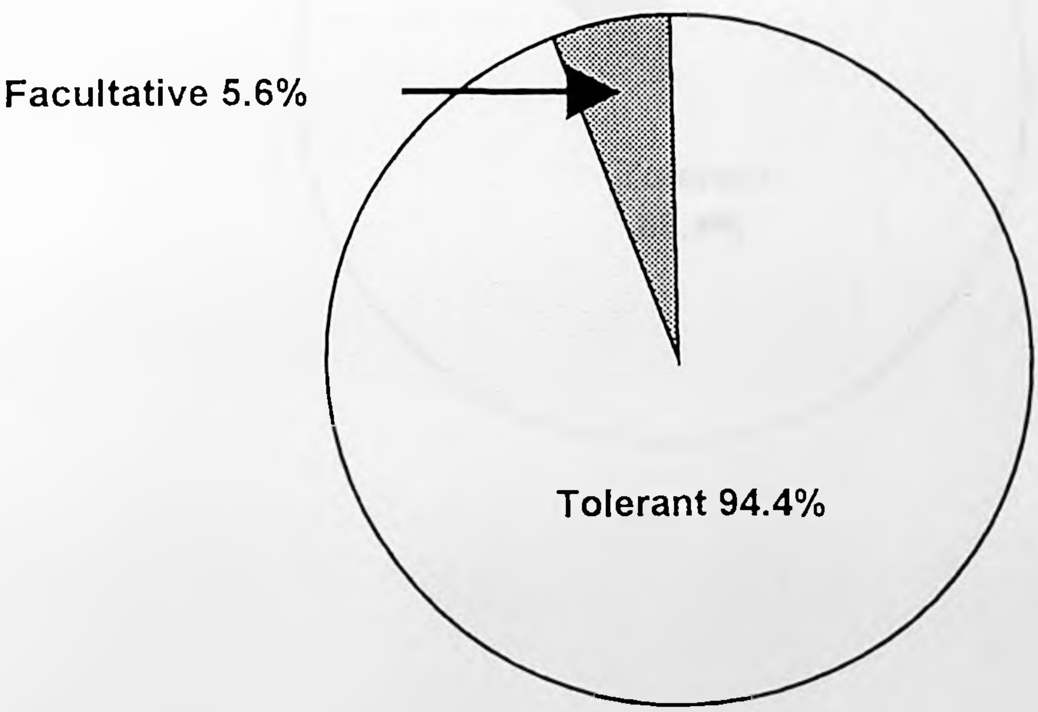


Fig. 3 Percent taxa according to tolerance value, Vance Branch 1997

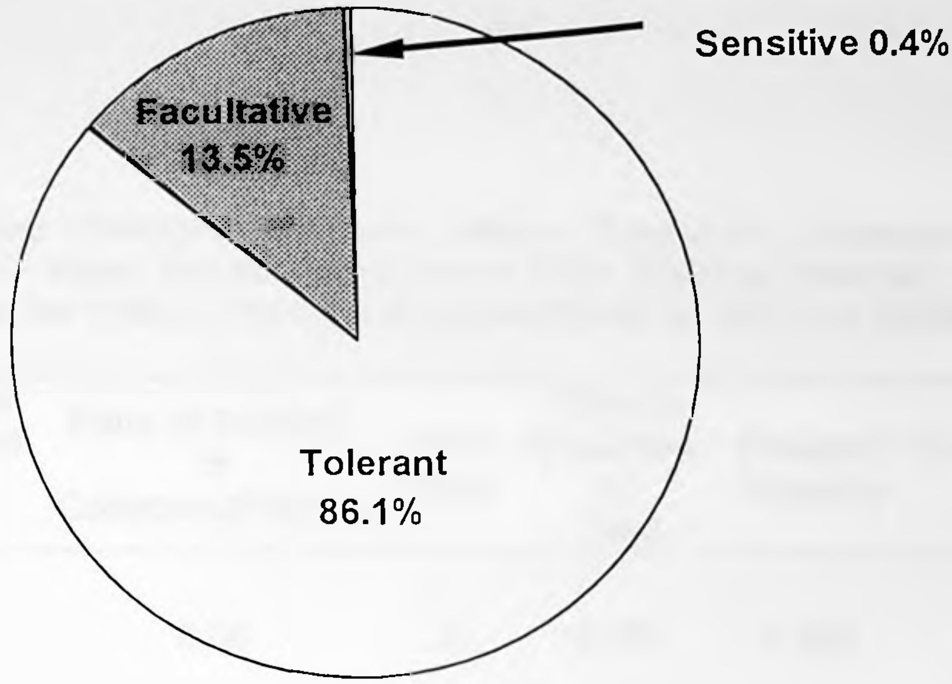


Fig. 4 Percent taxa according to tolerance value, Vance Branch 2000

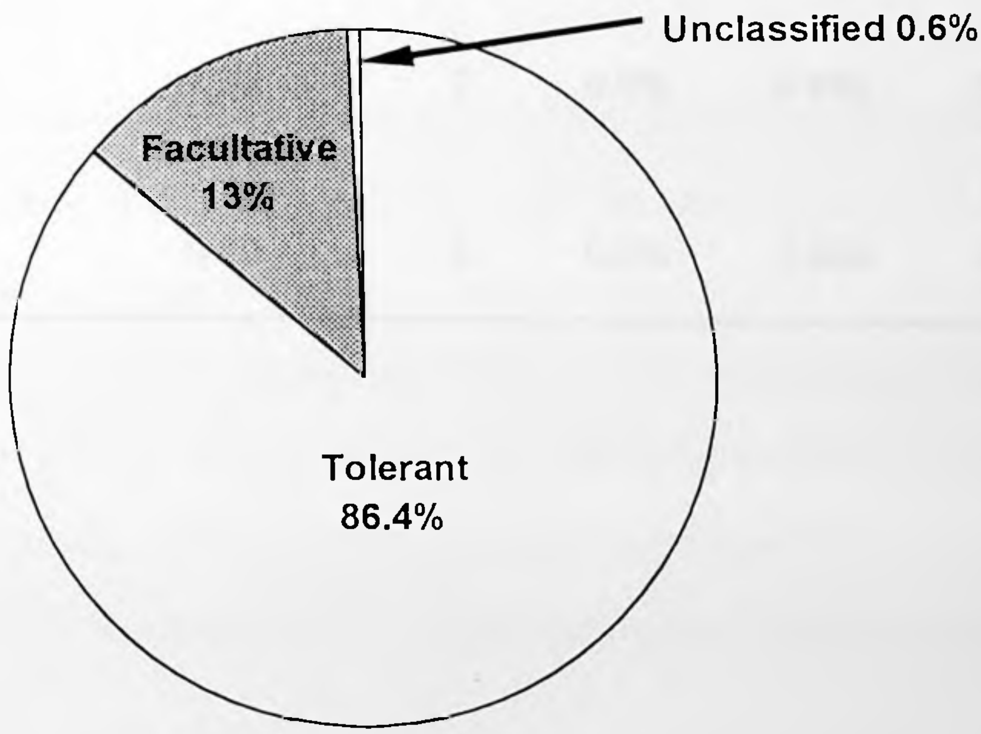


Table 3. Modified Hilsenhoff Biotic Index, Ratio of Scrapers to Collectors/ Filterers, EPT Index, Percent Shredders to Total, Shannon Diversity And Evenness for Rollem Fork #2 and Vance Branch in 1997 and 2000

Pond I.D.	Modified Hilsenhoff Biotic Index	Ratio of Scrapers to Collectors/Filterers	EPT Index	Percent Shredders to Total	Shannon Diversity	Evenness
Rollem Fork #2 1997	5.93	0:00	3	0.0%	1.405	0.421
Rollem Fork #2 2000	5.91	0:10	2	1.7%	0.504	0.210
Vance Branch 1997	5.67	4:33	7	0.0%	0.935	0.330
Vance Branch 2000	5.69	0:00	2	0.9%	0.958	0.346

Metric 3. Ratio of Scraper and Filtering Collector Functional Feeding Groups

Rollem Fork #2 had no scrapers present in the 1997 and 2000 samples and no filterers present in the 1997 sample. One taxon of filterers was found in the 2000 sample (Table 3). Vance Branch experienced a drop from a scraper/filterer ratio of 4:33 to a scraper/filterer ratio of 0:0 (Table 3). The loss of these particular taxa indicates a possible disturbance but it must be remembered that the scraper/filterer ratio is meant for riffle/run communities.

Metric 4. Ratio of EPT and Chironomidae Abundances

In 1997, Rollem Fork #2 had 18 EPT individuals for every 288 chironomids (Fig. 5). In 2000, there were 25 EPT individuals for every 672 chironomids. Although the total number of EPT individuals increased, their overall abundance as compared to chironomid presence decreased slightly because of the increase in chironomid abundance (Fig. 6). Vance Branch, however, experienced an increase in the ratio of EPT individuals to chironomids. In 1997, there were 149 EPT individuals to every 1006 chironomids (Fig. 7). In 2000, however, chironomid abundance dropped by 202 individuals. EPT abundance also decreased from 149 individuals in 1997 to 113 individuals in 2000 but the overall ratio increased slightly (Fig. 8).

Figure 5. Ratio of EPT and Chironomidae abundances, Rollem Fork #2 1997

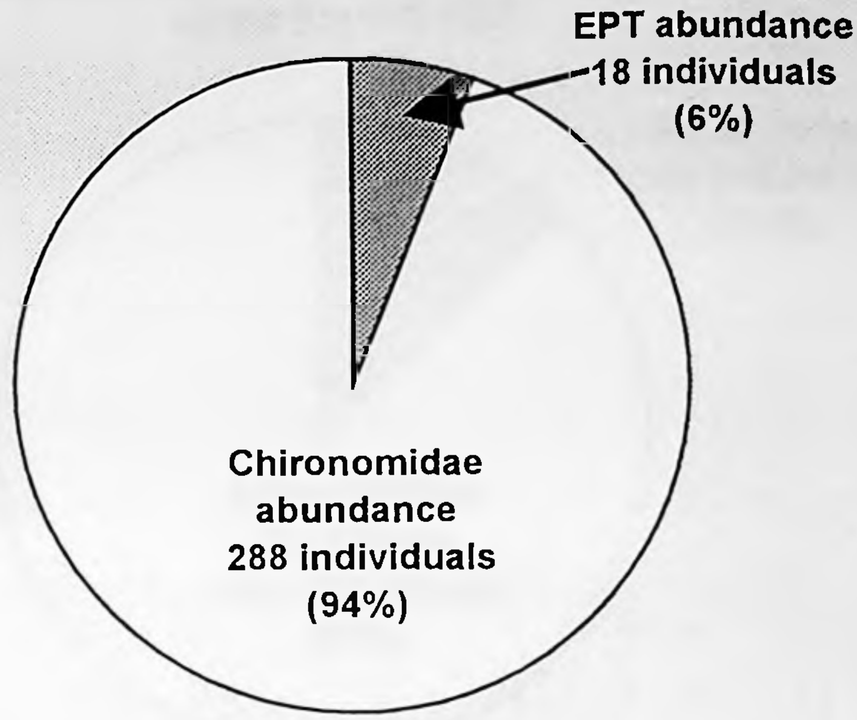


Figure 6. Ratio of EPT and Chironomidae abundances, Rollem Fork 2000

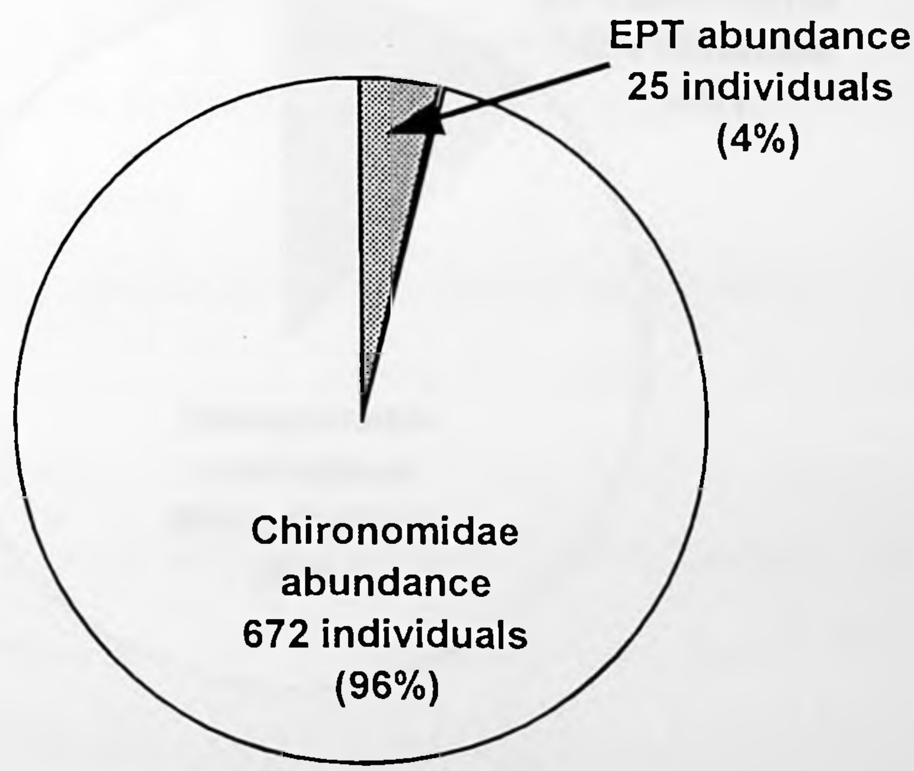


Figure 7. Ratio of EPT and Chironomidae Abundance, Vance Branch 1997

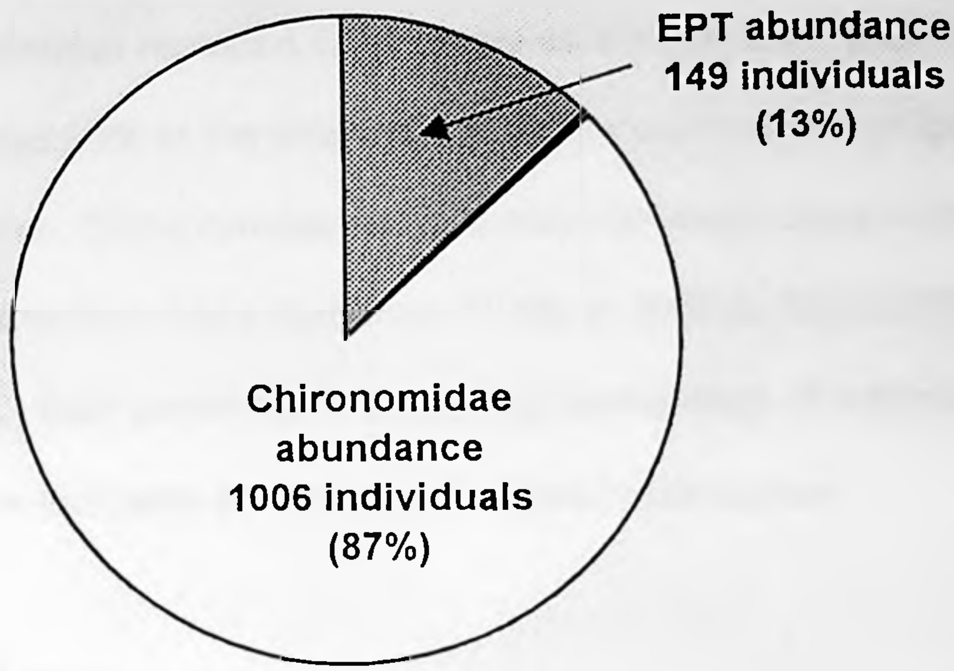
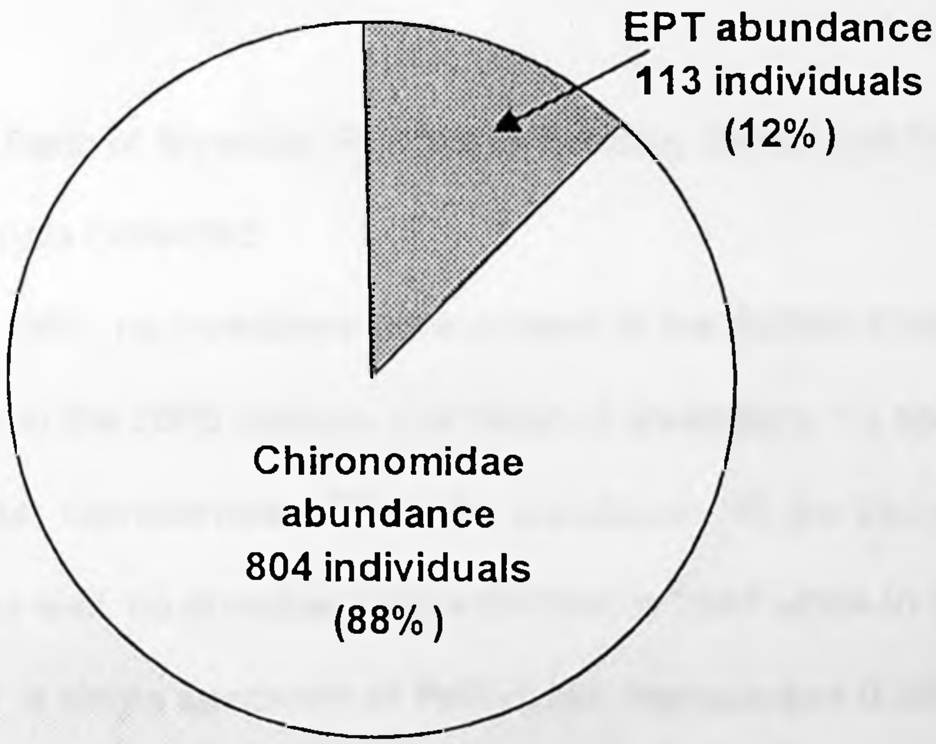


Figure 8. Ratio of EPT and Chironomidae Abundances, Vance Branch 2000



Metric 5. Percent Contribution of Dominant Taxon

In 1997, Oligochaete was the dominant taxon in Rollem Fork #2 and represented 47.9% of the individuals in the population. However, the family Chironomidae replaced Oligochaete as the dominant taxon in 2000 and represented 90% of the total individuals in the population (Figs. 9, 10). In Vance Branch, Chironomidae was the most dominant taxon in both years; its contribution decreased from 77.9% in 1997 to 76% in 2000 (Figs. 11, 12). Both ponds have a very high percentage of a dominating taxon, and this indicates environmental stress in the system.

Metric 6. EPT Index

The EPT index for Rollem Fork #2 decreased slightly from 3 taxa in 1997 to 2 taxa in 2000. In Vance Branch, the decrease was more dramatic, from 7 EPT taxa in 1997 to only 2 in 2000 (Table 3).

Metric 7. Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected

In 1997, no shredders were present in the Rollem Fork #2 sample. However, in the 2000 sample, one taxon of shredders, 13 specimens of *Peltodytes* , represented 1.7% of the population. In the Vance Branch sample as well, no shredders were present in 1997 while in 2000, one shredder, a single specimen of *Peltodytes*, represented 0.09% of the total population (Table 3).

Fig. 9. Percent Dominant Taxon for Rollem Fork #2, 1997

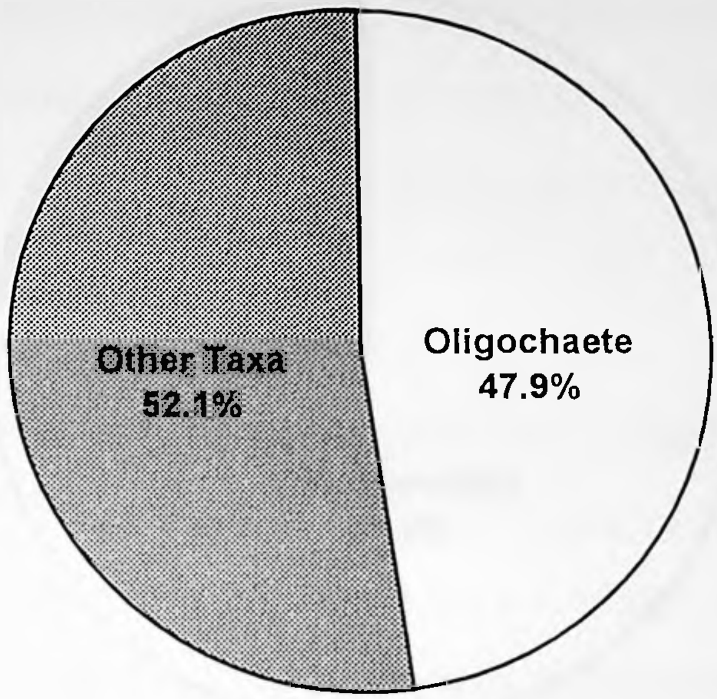


Fig. 10. Percent Dominant Taxon for Rollem Fork #2, 2000

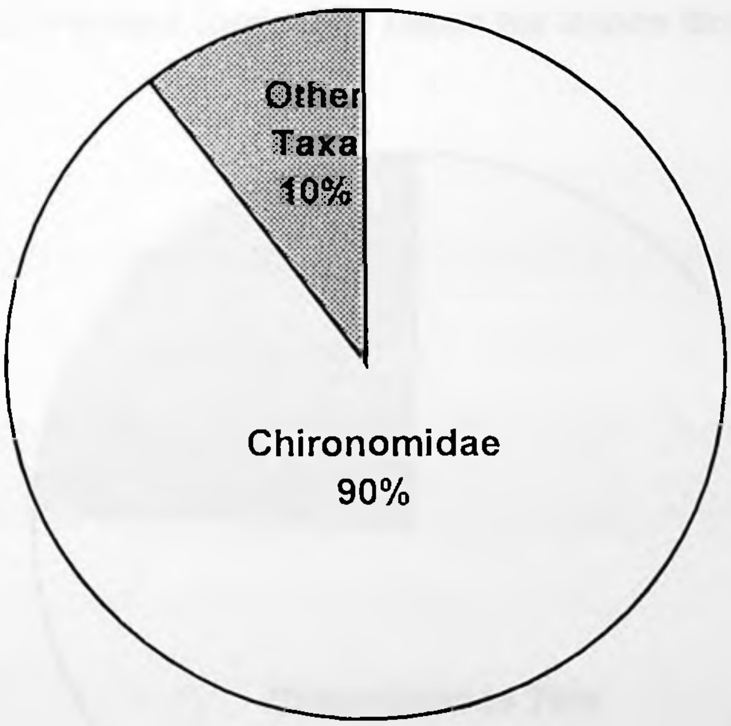


Fig. 11. Percent Dominant Taxon for Vance Branch, 1997

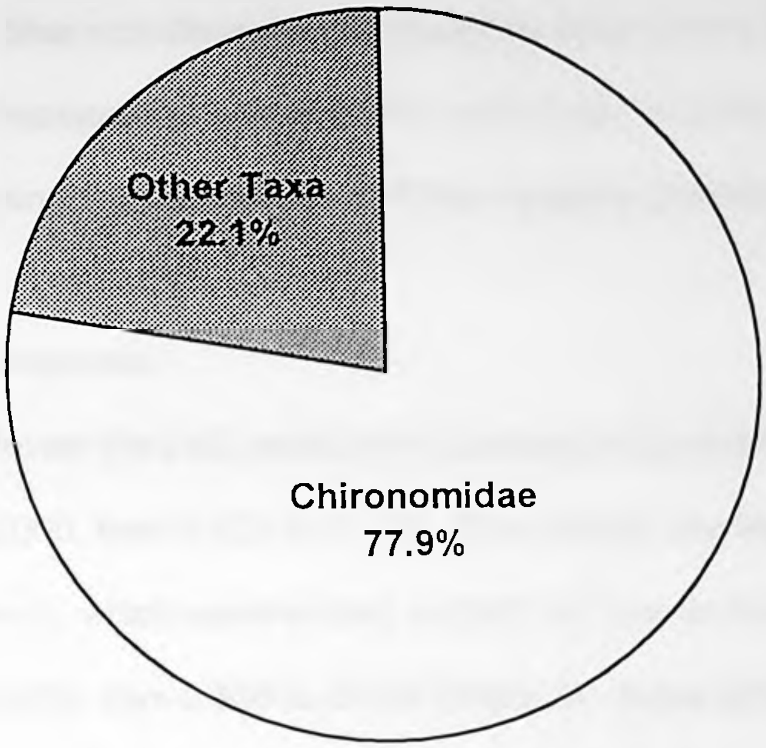
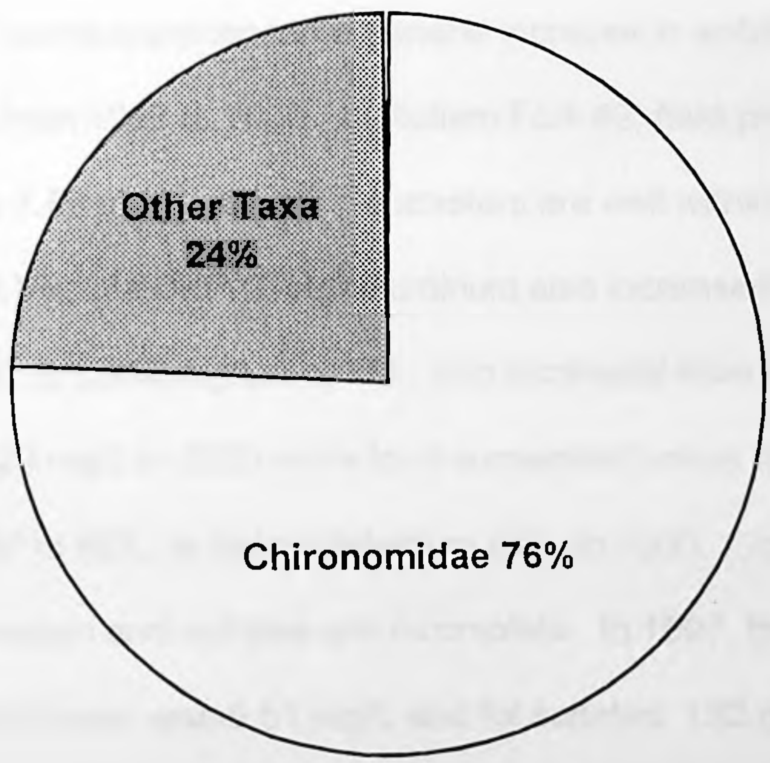


Fig. 12. Percent Dominant Taxon for Vance Branch, 2000



Metric 8. Shannon Diversity

The Shannon Diversity decreased for Rollem Fork #2 from 1.405 to 0.504 and increased in Vance Branch from 0.935 to 0.958. However, both ponds remained in the severely polluted category of scores (Table 3).

Metric 9. Evenness

In Rollem Fork #2, evenness decreased substantially between 1997 and 2000, from 0.421 to 0.210. The change was less dramatic for Vance Branch, which experienced a slight increase in evenness between 1997 and 2000, from 0.330 to 0.346 (Table 3). None of these numbers represent a particularly even distribution although the decrease in evenness in Rollem Fork #2 indicates somewhat worsening environmental conditions.

Water Chemistry

Both ponds experienced a general increase in water chemistry parameters from 1997 to 2000. In Rollem Fork #2, field pH increased from 7.68 to 7.89 although both parameters are well within limits set forth by the West Virginia DEP. Total aluminum also increased from 0.093 mg/L in 1997 to 0.250 mg/L in 2000. Iron increased from 0.273 mg/L in 1997 to 0.120 mg/L in 2000 while total suspended solids decreased from 5 mg/L in 1997 to BDL, or below detection limit, in 2000. Data for both dissolved oxygen and sulfates are incomplete. In 1997, the concentration of dissolved oxygen was 9.51 mg/L and for sulfates, 133 mg/L, both within acceptable limits. No data were made available for the 2000 sampling season, however. Conductivity data was unavailable for both years (Tables 4 and 6).

Water chemistry data were more complete for Vance Branch. Total field pH increased from 7.26 in 1997 to 8.67 in 2000, both within acceptable limits. Aluminum, however, decreased from 0.104 mg/L in 1997 to BDL, or below detection limit in 2000, indicating that aluminum concentrations were so low as to be undetectable by sampling equipment. Iron concentrations decreased from 0.204 mg/L in 1997 to 0.060 mg/L in 2000. Both of these concentrations meet the acceptable limit for iron of 1.5 mg/L. Total suspended solids decreased from 11 mg/L in 1997 to 6 mg/L in 2000; both of these concentrations comply with the acceptable limit of 500 mg/L. Conductivity data was available for Vance Branch. In 1997, conductivity was 701 umhos/com while in 2000 it increased to 1320 umhos/cm. Neither of these is within the accepted limit of 500 umhos/cm. Sulfates also increased from 1997 to 2000, from 211 mg/L to 762 mg/L. The 1997 concentration complied with the DEP limits but the 2000 concentration exceeded the limit of 250 mg/L. Dissolved oxygen data was missing for Vance Branch in 2000. In 1997, however, the concentration was 8.92 mg/L, which complied with the acceptable limit of greater than 5 mg/L (Tables 5 and 6)

Table 4. Water chemistry data for Rollem Fork #2, 1997 and 2000.
BDL= Below Detection Limit

Parameter	1997	2000
Field pH	7.68	7.89
Aluminum (Al) Total	0.093 mg/L	0.25 mg/L
Solids, Total Suspended	5 mg/L	BDL mg/L
Iron (Fe), Total	0.273 mg/L	0.12 mg/L
Oxygen	9.51 mg/L	-
Sulfates	133 mg/L	-

Table 5. Water Chemistry Data for Vance Branch, 1997 and 2000
BDL= Below Detection Limit

Parameter	1997	2000
Field pH	7.26	8.67
Sulfate, Total - Turbidity	211 mg/L	762 mg/L
Aluminum, Total	0.104 mg/L	801 mg/L
Solids, Total Dissolved	534 mg/L	1100 mg/L
Oxygen	8.92 mg/L	-
Conductivity, Total	701 umhos/cm	1320 umhos/cm

Table 6. Acceptable parameters for water chemistry as set forth by the West Virginia DEP Environmental Quality Board (2000).

Parameter	Concentration
Field pH	6-9
Aluminum (Al), Total	0.750 mg/L
Iron (Fe), Total	1.5 mg/L
Solids, Total Suspended	500 mg/L
Sulfate, Total	250 mg/L
Conductivity	500 umhos/cm
Total Dissolved Oxygen	> 5 mg/L

Seasonal Study

Dissimilarity between the same seasons of different ponds

Using the STATISTICA multivariate cluster analysis of dissimilarity, a simultaneous comparison was allowed between the reference site, a one-time sample taken at Honey Branch in fall 1999, and each seasonal sample of the three ponds. In the fall of 1999, WB3, the youngest of the three ponds, was the least dissimilar (or most similar) to the reference, Honey Branch (HBREF) with a percent dissimilarity of 52%. WB5, the oldest of the three experimental ponds, was the most dissimilar to the reference; it was 62% dissimilar to HBREF. The percent dissimilarity between WB4 and the reference was between that of WB3 and WB5 at 55% (Fig. 13, Table 7).

The same trend can be seen when the winter 2000 sample is compared to the reference. Again, WB3 was the least dissimilar to the reference sample having a percent dissimilarity of 48% while WB5 was the most dissimilar at 59%. WB4 ranges between WB3 and WB5 with a percent dissimilarity of 55% (Fig. 14, Table 8). There was a slight change in dissimilarity order in spring 2000. While WB3 remained the least dissimilar to HBREF at 52% dissimilarity, WB4 became the most dissimilar to HBREF with a percent dissimilarity of 62%.

In spring 2000, WB5 was 55% dissimilar to HBREF, which is between WB3 and WB4 (Fig. 15, Table 9). In summer 2000, WB3 remained the least dissimilar to HBREF at 55%. However, WB5 became dramatically more dissimilar to HBREF, jumping from 55% dissimilar in spring 2000 to 76% dissimilar in the summer sample. WB4 also increased in dissimilarity, moving from 62% dissimilar in spring 2000 to 69% dissimilar to HBREF in summer 2000 (Fig. 16, Table 10).

The last season of sampling, fall 2000, showed the same trend as the other seasons. WB3 remained the least dissimilar to HBREF at 59%. WB4 dropped back to the spring 2000 dissimilarity of 62% and WB5, while it did drop from the dissimilarity of summer 2000, remained the most dissimilar to HBREF at 66% (Fig. 17, Table 11).

Figure 13. Percent disagreement between all ponds and reference, fall 1999

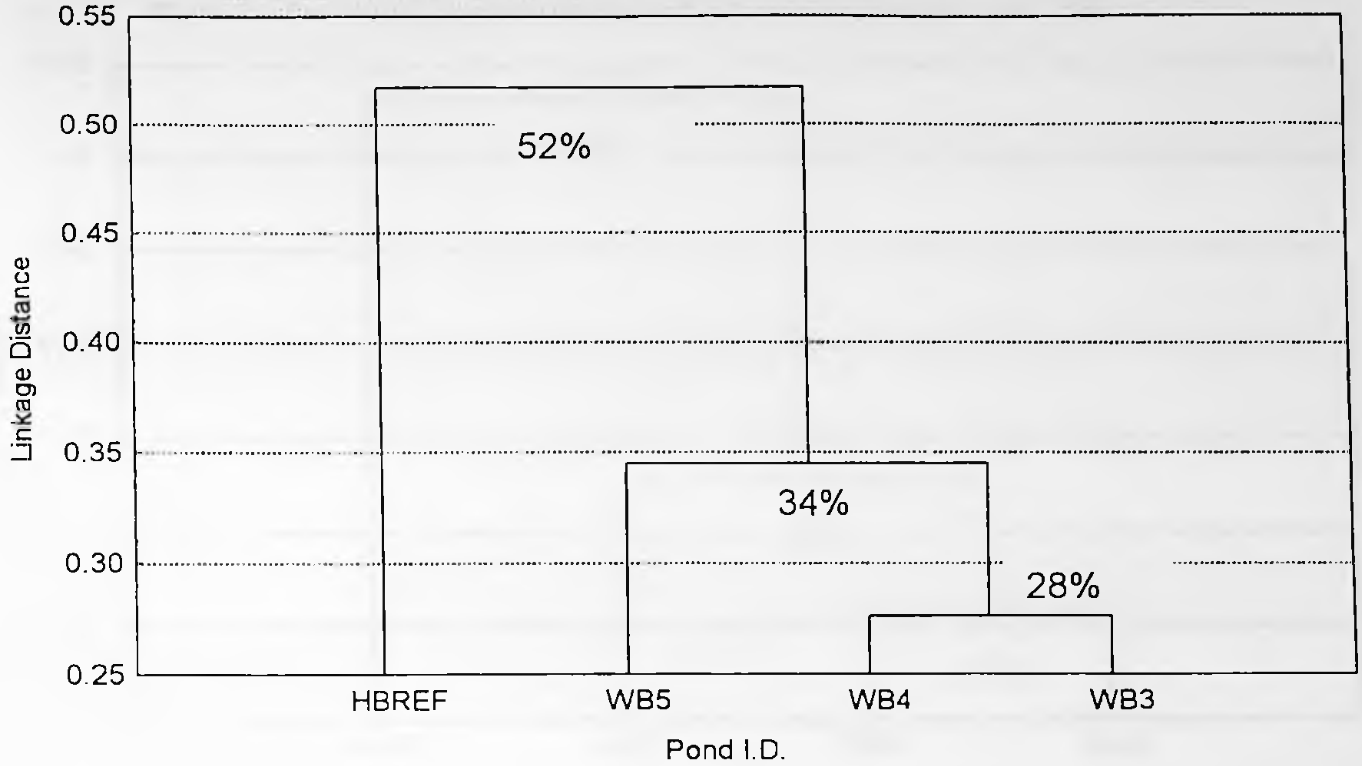


Table 7. Cluster analysis for percent disagreement between all ponds and reference, fall 1999

Statistical Cluster Analysis	WB3	WB4	WB5	HBREF
WB3	.00	.28	.38	.52
WB4	.28	.00	.34	.55
WB5	.38	.34	.00	.62

Figure 14. Percent disagreement between all ponds and reference, winter 2000

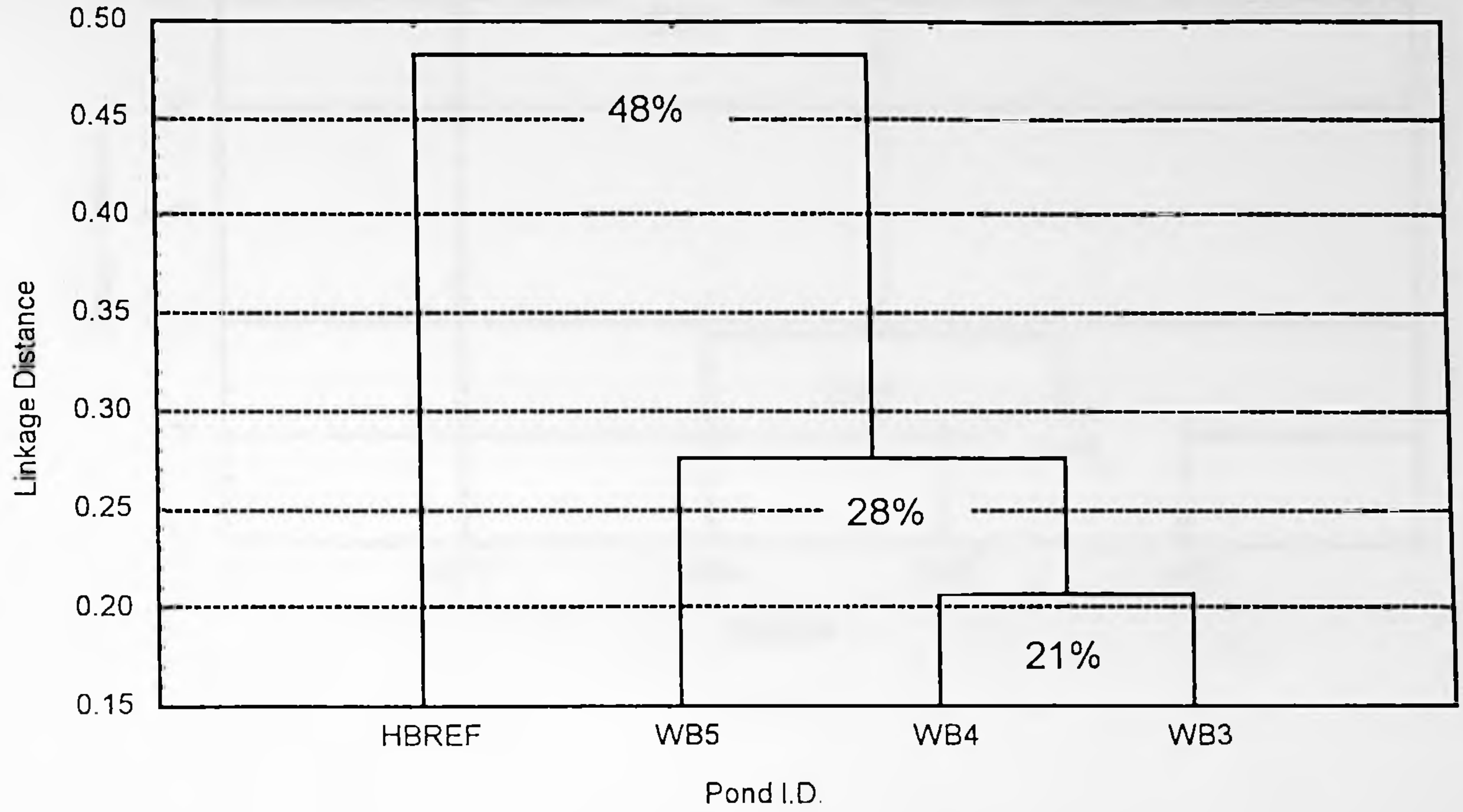


Table 8. Cluster analysis for percent disagreement between all ponds and reference, winter 2000

Statistical Cluster Analysis	WB3	WB4	WB5	HBREF
WB3	.00	.21	.28	.48
WB4	.21	.00	.34	.55
WB5	.28	.34	.00	.59

Figure 15. Percent disagreement between all ponds and reference, spring 2000

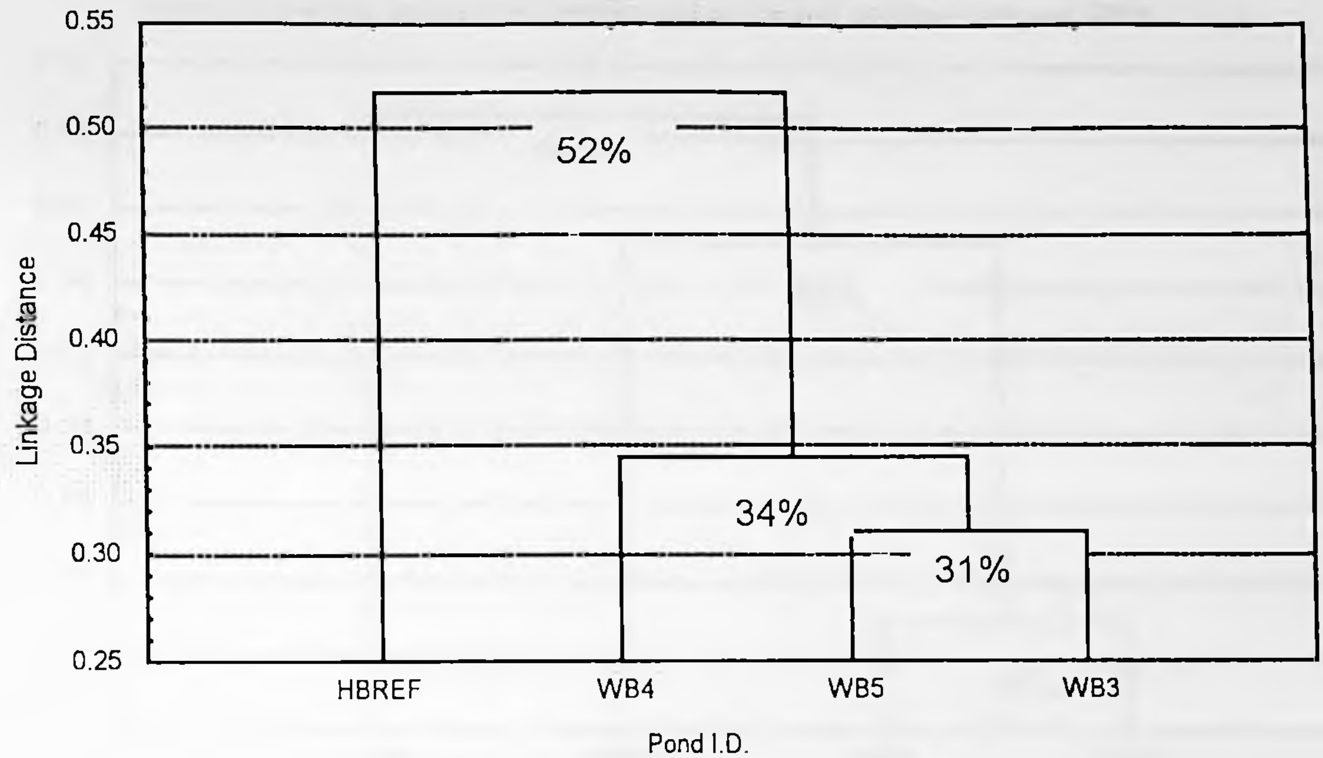


Table 9. Cluster analysis of percent disagreement between all ponds and reference, spring 2000.

Statistical Cluster Analysis	WB3	WB4	WB5	HBREF
WB3	.00	.34	.31	.52
WB4	.34	.00	.34	.62
WB5	.31	.34	.00	.55

Figure 16. Percent disagreement between all ponds and reference, summer 2000

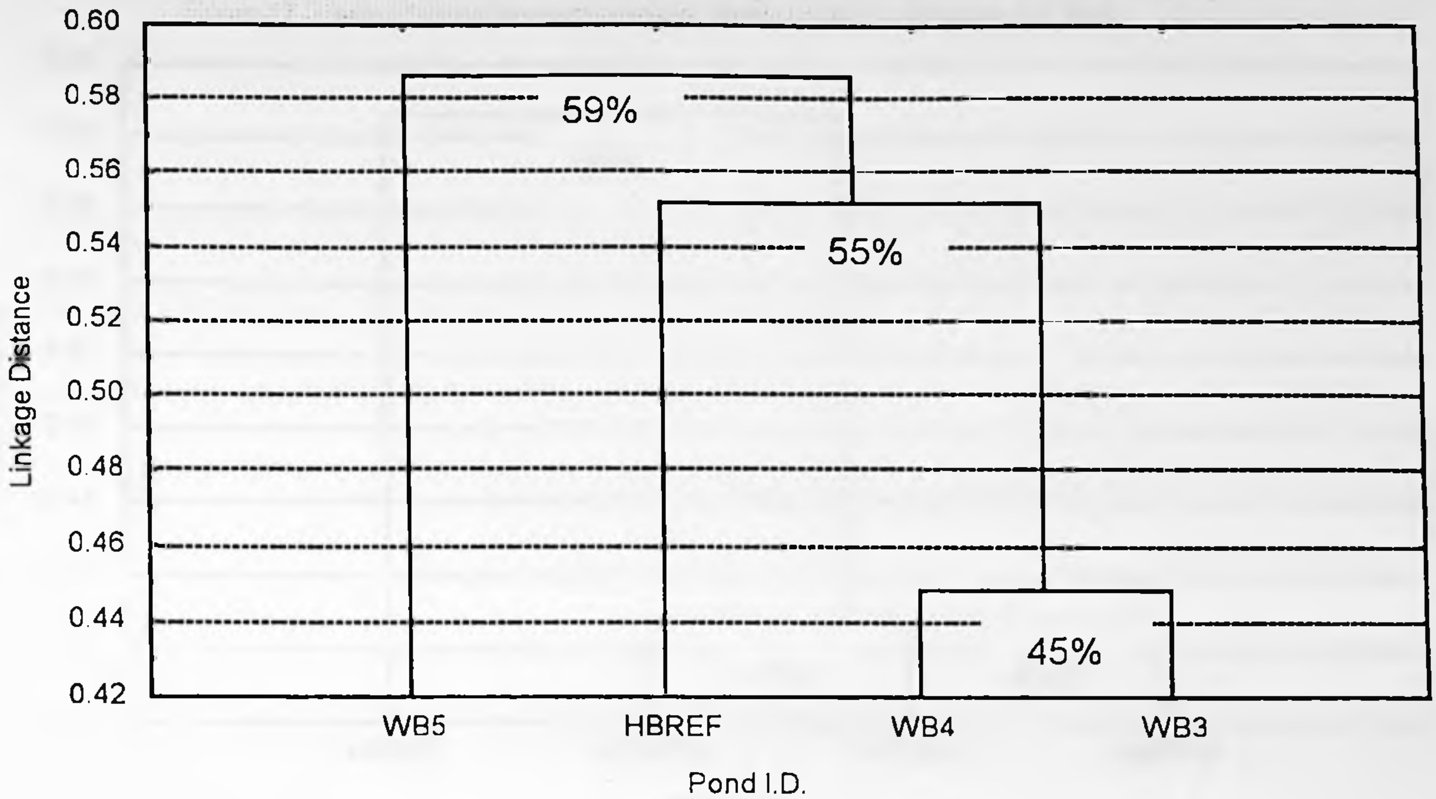


Table 10. Cluster analysis for percent disagreement between all ponds and reference, summer 2000

Statistical Cluster Analysis	WB3	WB4	WB5	HBREF
WB3	.00	.45	.59	.55
WB4	.45	.00	.66	.69
WB5	.59	.66	.00	.76

Figure 17. Percent disagreement between all ponds and reference, fall 2000

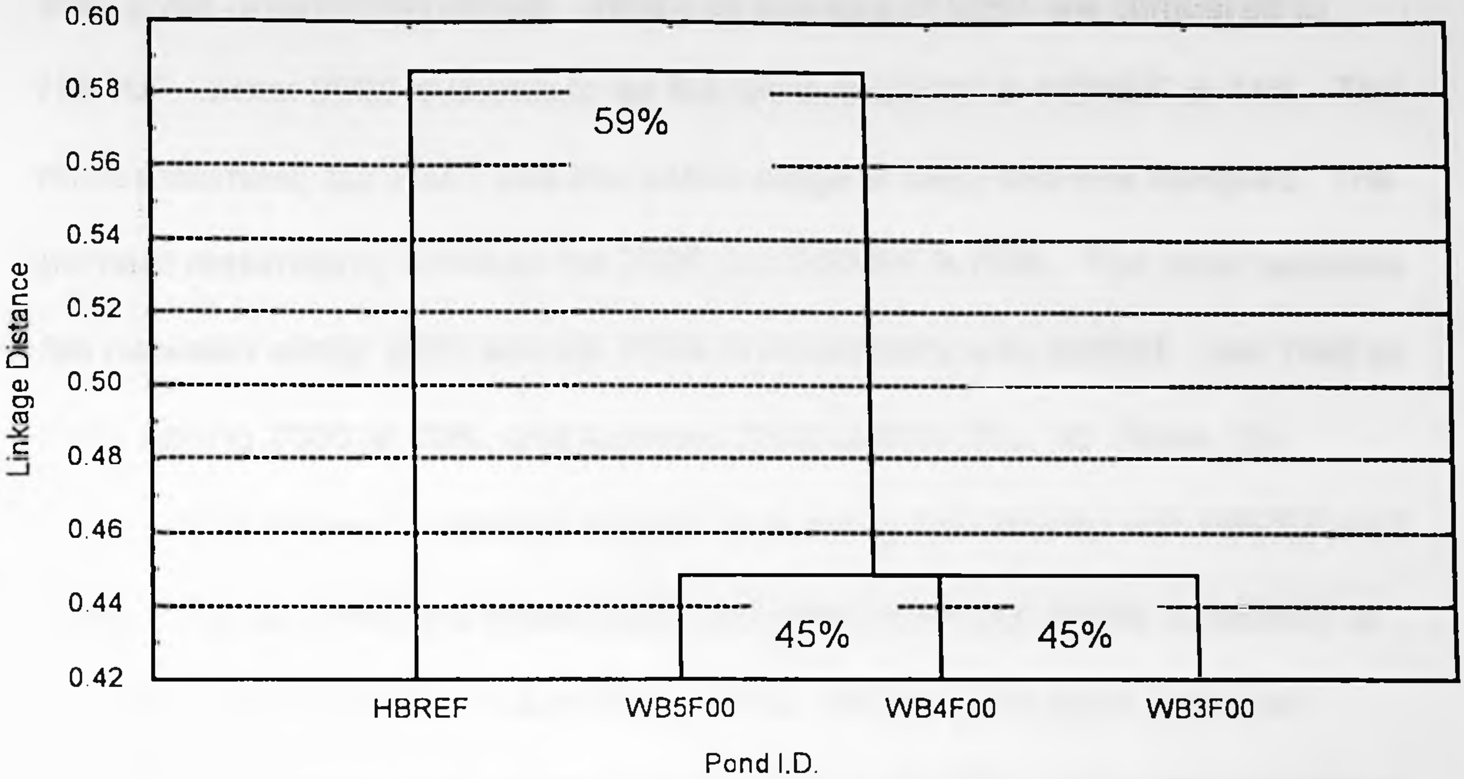


Table 11. Cluster analysis for percent disagreement between all ponds and reference, fall 2000

Statistical Cluster Analysis	WB3	WB4	WB5	HBREF
WB3	.00	.45	.45	.59
WB4	.45	.00	.48	.62
WB5	.45	.48	.00	.66

Dissimilarity between different seasons of the same pond

Comparing every season of the same pond to HBREF at the same time also gives unexpected results. When all seasons of WB3 are compared to HBREF, winter 2000 is shown to be the least dissimilar to HBREF at 74%. The most dissimilar, fall 2000, was the oldest stage of WB3 that was sampled. The percent dissimilarity between fall 2000 and HBREF is 89%. The other seasons fell between winter 2000 and fall 2000 in dissimilarity with HBREF - fall 1999 at 79%, spring 2000 at 79%, and summer 2000 at 84% (Fig. 18, Table 12).

WB4 showed a trend of slightly increasing dissimilarity with HBREF as it aged. The fall 1999 and winter 2000 samples were most similar to HBREF at 55% dissimilarity for both sampling periods. As the pond aged, however, similarity increased and reached a peak in summer 2000 with a dissimilarity of 69%. The dissimilarity dropped again to 62% in fall 2000 (Fig. 19, Table 13). However, it is interesting to note that the fall 2000 sample, the oldest stage of the pond sampled, was more dissimilar to the reference than the fall 1999 sample, the youngest stage of the pond sampled.

In the case of WB5, dissimilarity to HBREF dropped with each season from 69% in fall 1999 to 65% in winter 2000 to the spring 2000 sample, which was the least dissimilar to HBREF at 62% dissimilarity. This drop followed the expected trend. However, in summer 2000 dissimilarity to HBREF increased dramatically to a high of 85% dissimilar. Dissimilarity dropped again to 73% in fall 2000 but still remained higher than the fall 1999, winter 2000, and spring 2000 sampling seasons (Fig. 20, Table 14).

Figure 18. Percent disagreement between all seasons of WB3 and reference

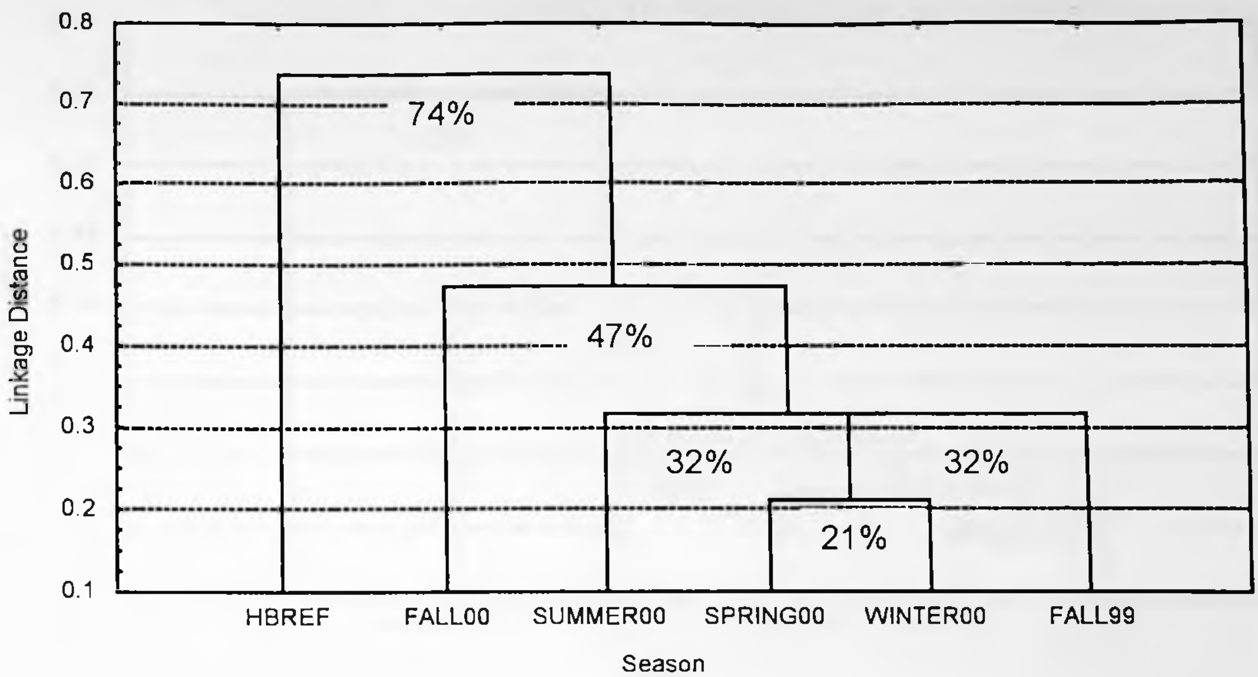


Table 12. Cluster analysis of percent disagreement between all seasons of WB3 and reference

Statistical Cluster Analysis	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	HBREF
Fall 1999	.00	.32	.37	.42	.47	.79
Winter 2000	.32	.00	.21	.32	.53	.74
Spring 2000	.37	.21	.00	.37	.58	.79
Summer2000	.42	.32	.37	.00	.53	.84
Fall 2000	.47	.53	.58	.53	.00	.89

Figure 19. Percent disagreement between all seasons of WB4 and reference

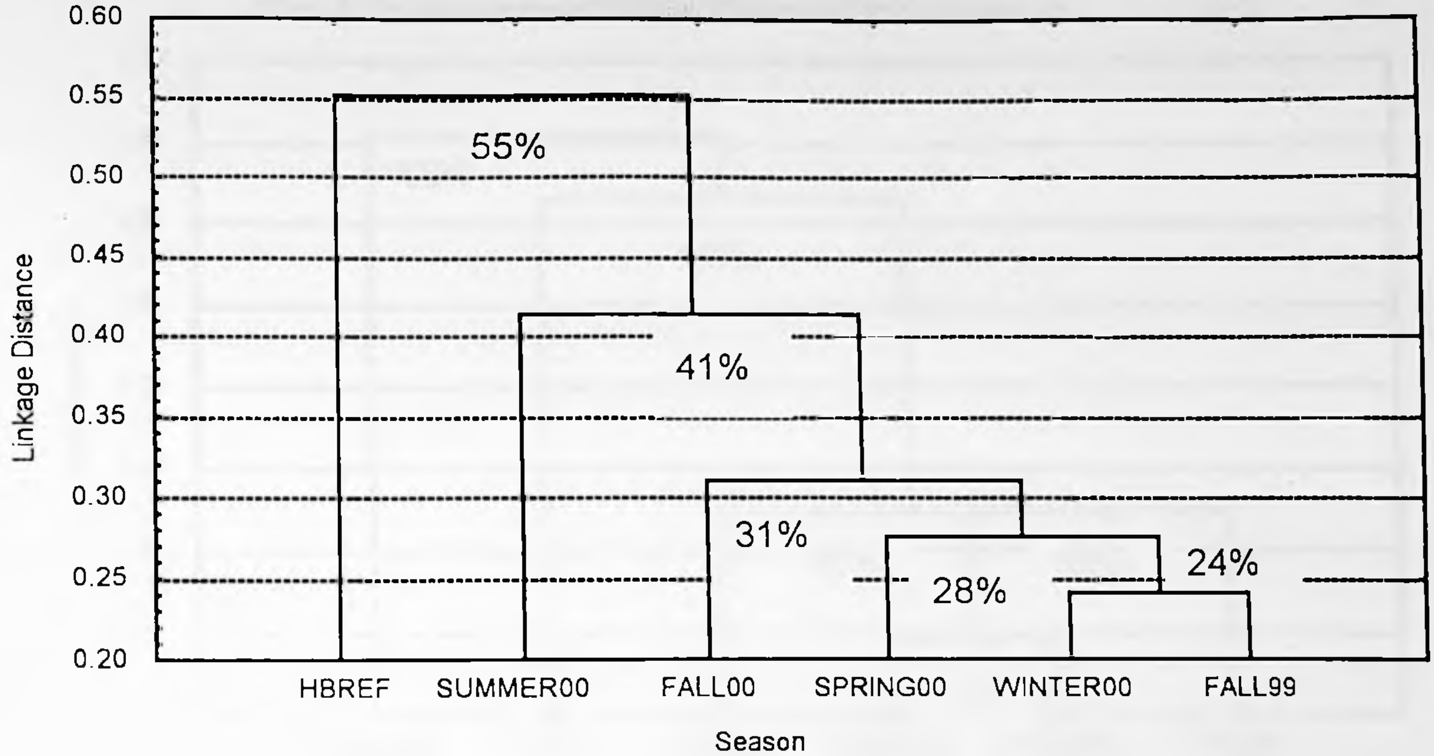


Table 13. Cluster analysis for percent disagreement between all seasons of WB4 and reference

Statistical Cluster Analysis	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	HBREF
Fall 1999	.00	.24	.31	.41	.34	.55
Winter 2000	.24	.00	.28	.48	.31	.55
Spring 2000	.31	.28	.00	.48	.38	.62
Summer 2000	.41	.48	.48	.00	.48	.69
Fall 2000	.34	.31	.38	.48	.00	.62

Figure 20. Percent disagreement between all seasons of WB5 and reference

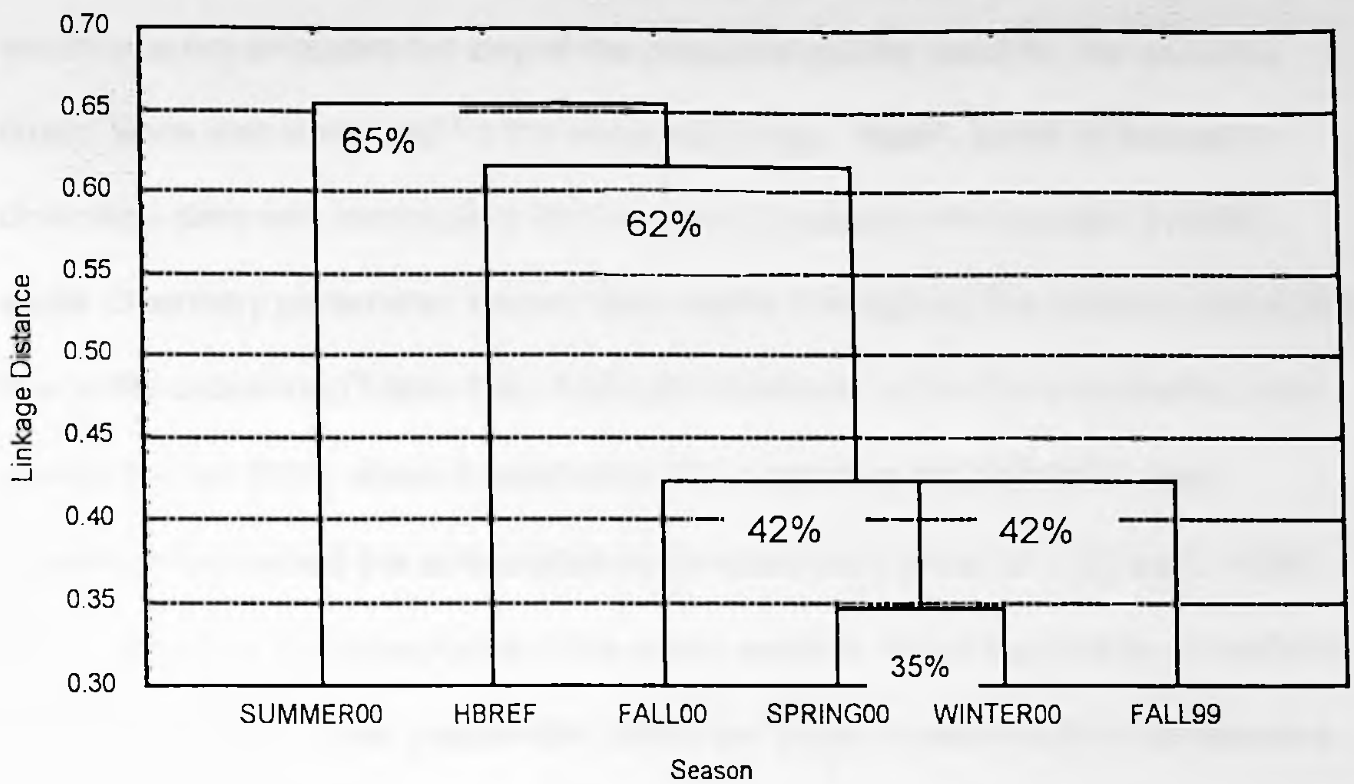


Table 14. Cluster analysis for percent disagreement between all seasons of WB5 and reference

Cluster analysis	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	HBREF
Fall 1999	.00	.42	.46	.69	.54	.69
Winter 2000	.42	.00	.35	.65	.42	.65
Spring 2000	.46	.35	.00	.65	.46	.62
Summer 2000	.69	.65	.65	.00	.73	.85
Fall 2000	.54	.42	.46	.73	.00	.73

Water Chemistry

The same water chemistry parameters, except for dissolved oxygen, which was not available for any of the seasonal ponds, used for the one-time study, were also analyzed for the seasonal study. Again, some of the water chemistry data was incomplete for the varying seasons and ponds. In WB3, water chemistry parameter stayed fairly stable throughout the seasons with just a few shifts occurring (Table 15). Field pH remained within the acceptable limits except for fall 2000, when it reached 9.38, exceeding the limit of 9. Also, aluminum exceeded the acceptable parameters only once, at 1.21 mg/L in fall 1999. Iron met the acceptable limits every season, never exceeding acceptable limit of 1.5 mg/L. Total suspended solids fell within normal limits in all seasons, in fall 1999 at 17 mg/L and fall 2000 at 6 mg/L, and in all other seasons at BDL, or below detection limit. Conductivity remained within limits in all seasons as did total sulfates.

Water chemistry data for WB4 was unavailable for summer and fall 2000. In the other seasons, however, parameters closely followed those of WB3 (Table 16). Field pH always remained within acceptable limits as did conductivity and total sulfates. Aluminum was within acceptable limits in all seasons; in fall 1999 with a concentration of 0.30 mg/L, and in winter and spring 2000 at BDL, or below detection limit. Iron concentration always complied, never exceeding acceptable limits in all reported seasons. Total suspended solids met acceptable limits in all seasons as well.

Water chemistry data for WB5 was not provided for the fall 1999, winter 2000, and summer 2000 seasons. Field pH and total iron exceeded acceptable limits in spring 2000 while all other parameters were within limits (Table 17). In fall 2000, however, pH fell back into acceptable limits while iron remained high and aluminum concentration decreased to BDL , well under the limit of 0.750 mg/L.

Honey Branch water chemistry data reveals the same basic trend as the other ponds (Table 18). Field pH, aluminum, iron, total suspended solids, sulfates, and conductivity were well within acceptable limits.

Table 15. Water chemistry parameters for all seasons of WB3 compared with acceptable limits as established by the West Virginia DEP Water Quality Board (2001).

Parameter	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	WVDEP Limits
pH	7.36	7.32	6.94	8.0	9.38	6-9
Aluminum (Al), Total	1.21 mg/L	0.13 mg/L	0.12 mg/L	0.14 mg/L	0.31 mg/L	0.750 mg/L
Iron (Fe), Total	0.57 mg/L	0.07 mg/L	0.16 mg/L	0.06 mg/L	0.05 mg/L	1.5 mg/L
Solids, Total Suspended	17 mg/L	801 mg/L	801 mg/L	801 mg/L	6 mg/L	500 mg/L
Conductivity, Total	240 umhos/cm	321 umhos/cm	190 mg/L	459 umhos/cm	337 umhos/cm	500 umhos/cm
Sulfate, Total	49.6 mg/L	82.0 mg/L	21 mg/L	78 mg/L	72.2 mg/L	250 mg/L

Table 16. Water chemistry parameters for all seasons of WB4 compared with acceptable limits as established by the West Virginia DEP Water Quality Board (2001).

Parameter	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	WVDEP Limits
pH	7.68	7.61	7.53	-	-	6-9
Aluminum (Al), Total	0.30 mg/L	801 mg/L	801 mg/L	-	-	0.750 mg/L
Iron (Fe), Total	0.10 mg/L	0.12 mg/L	0.38 mg/L	-	-	1.5 mg/L
Solids, Total Suspended	7.0 mg/L	801 mg/L	801 mg/L	-	-	500 mg/L
Conductivity, Total	290 umhos/cm	371 umhos/cm	319 mg/L	-	-	500 umhos/cm
Sulfate, Total	72.0 mg/L	188 mg/L	63.4 mg/L	-	-	250 mg/L

Table 17. Water chemistry parameters for all seasons of WB5 compared to acceptable limits as established by the West Virginia DEP Water Quality Board (2001).

Parameter	Fall 1999	Winter 2000	Spring 2000	Summer 2000	Fall 2000	WVDEP Limits
pH	-	-	9.24	-	8.78	6-9
Aluminum (Al), Total	-	-	0.26 mg/L	-	801 mg/L	0.750 mg/L
Iron (Fe), Total	-	-	0.43 mg/L	-	801 mg/L	1.5 mg/L
Solids, Total Suspended	-	-	6.0 mg/L	-	8 mg/L	500 mg/L
Conductivity, Total	-	-	393 mg/L	-	447 mg/L	500 umhos/cm
Sulfate, Total	-	-	63.4 mg/L	-	132 mg/L	250 mg/L

Table 18. Water chemistry parameters for Honey Branch (HBREF) compared with acceptable limits as established by the West Virginia DEP Water Quality Board (2001).

Parameter	HBREF 11/1/99	WVDEP Limits
pH	7.07	6-9
Aluminum (Al), Total	0.37	0.750 mg/L
Iron (Fe), Total	0.78	1.5 mg/L
Solids, Total Suspended	5.0	500 mg/L
Conductivity, Total	357	500 umhos/cm
Sulfate, Total	56	250 mg/L

Discussion

Benthos comparison in Rollem Fork #2 and Vance Branch, 1997 and 2000

The EPA Rapid Bioassessment Protocols applied to the Rollem Fork #2 and Vance Branch ponds in 1997 and 2000 indicated little change in the condition of the ponds. Taxa richness did not change for either pond, which indicates that overall there is no net influx of new taxa. In the case of Rollem Fork #2, the percentage of tolerant and facultative species did not change noticeably (Fig. 1). Vance Branch experienced a more noticeable change. Percent tolerant taxa remained almost the same; however, the loss of sensitive species from 1997 to 2000 indicates increased perturbation in the pond. These species were replaced by unclassified species, *Notonecta* and *Lestes*. Both families to which these species belong are represented in the sample by other members, all of which are either tolerant or facultative (Table 2). Nevertheless, the percentage represented by the loss of sensitive species and gain of unclassified species was so small that the change may be insignificant.

The modified Hilsenhoff Biotic Index, although it increased slightly in both ponds between 1997 and 2000, did not change enough to indicate either degradation or improvement. The index indicated a moderately polluted system for both ponds for both years (Table 3). There was little change in the ratio of scraper and filtering collector functional feeding groups for Rollem Fork #2, while Vance Branch experienced a loss of the scraper and filterer functional feeding groups. While this ratio may seem to indicate an extremely disturbed system upon first examination, it must be remembered that this and all Rapid Bioassessment metrics are designed for lotic systems. Filterer and collector functional feeding groups are more likely to be found in lotic environments where the constant influx of new organic matter and riffle areas can support these groups. In Rollem Fork #2 and Vance Branch, while there is some overhanging vegetation that can contribute new organic matter, it is not of the volume usually found in riparian areas. Also, the ponds have no water flow or shallow riffle areas that are the typical habitat of some of these feeding groups.

When comparing Ephemeroptera, Plecoptera, and Trichoptera abundances with Chironomidae abundances, there is a disproportionately high number of chironomids as compared to the more sensitive EPT taxa. However, Williams (1997) found that, in temporary ponds constructed in Britain, North America, and Australia, chironomids were among the small variety of invertebrates that are characteristic of the pond habitats. No members of the orders Ephemeroptera, Plecoptera, or Trichoptera were among the common inhabitants. The ability of the mostly tolerant chironomids, makes it a suitable candidate for living in a pond community. They are able to tolerate harsh physiological conditions, modify their life history, and migrate after emergence from the larval stage (Williams, 1997). This may also explain why Chironomidae is the most dominant taxon in Rollem Fork #2 in 2000 and in both years of Vance Branch.

In many temporary or new ponds, there is a definite pattern for succession of benthic macroinvertebrates. Dipterans, which include chironomids, appear first followed by the insect orders Coleoptera, Ephemeroptera, and Odonata (Layton et al., 1991). This trend is followed in Rollem Fork #2 and Vance Branch alike. There were several species that belong to Ephemeroptera, Coleoptera, and Odonata present in both ponds although not in great abundance as is reflected for Ephemeroptera by a low EPT index for both ponds in both years (Table 3). The low ratio of the shredder functional feeding group and the total number of individuals collected also indicates a disturbed system. Once again, the Rapid Bioassessment Protocols are meant for lotic systems and shredder functional feeding groups are more likely to be found in riffle areas.

The Shannon diversity and evenness metrics, as the other metrics, indicated that the ponds systems experience disturbance and are relatively polluted. Because the Shannon diversity and evenness values are based on taxa richness, however, it is expected that the values for these metrics will be low since pond environments tend to have a low diversity of species as mentioned before.

Upon examination of all of these metrics combined, a question should be raised as to the validity of using the EPA Rapid Bioassessment Protocols to gauge health of the ponds. The results as a whole can be used to indicate that there is little change in metrics between 1997 and 2000 and therefore no measurable succession. However, they also suggest that the ponds are moderately to severely disturbed, which is not necessarily the case. Rollem Fork

#2 and Vance Branch show similar benthic composition to temporary ponds in other studies. The cyclic nature of ponds, while they do not allow for the great diversity of species found in lotic systems, encourage the success of small numbers of adaptable species (Williams, 1997). If the ponds were stream environments, the results of the EPA Rapid Bioassessment Protocols would be cause for concern.

The fact that the protocols used in the Rollem Fork #2 and Vance Branch study are biased against pond environments brings forth the question of what are good protocols for assessing the health and succession of pond environments. A measure of community similarity would more accurately gauge whether a pond system is undergoing succession. The Bray-Curtis similarity index analyzes the presence and relative abundance of all taxa simultaneously and is probably the strongest tool for comparing two different sample years. The index ranges from 0 to 1, with 1 being the most similar. This index, teamed with the total density of benthics in each sample, taxa richness, and Shannon Diversity, can more accurately measure the health and succession of a pond system (Christman and Voshell, 1993).

Water chemistry did not seem to play a large role in the succession of benthics in Rollem Fork #2 and Vance Branch. The parameters, while some exceeded acceptable limits for drinking water, remained relatively stable over the course of the two sampling events (Tables 4 and 5).

Seasonal Study

In the comparison of dissimilarity between the same seasons of different ponds, WB3, the youngest pond, was always the least dissimilar, or most similar to the reference (HBREF). This results go against the logic that, as the ponds age, they will become more like the older reference pond. These results, in fact, show the opposite, that as the ponds age, they become less and less like the reference pond. In most seasons, WB5, the oldest of the three experimental ponds, was the most dissimilar to HBREF, while WB4 ranged between WB3 and WB5. Only once did WB4 become the most dissimilar to HBREF (Figs. 13, 14, and 15).

This phenomenon can also be illustrated by examining all seasons of WB3, the least dissimilar pond to HBREF. The oldest stage of WB3, fall 2000 was the most dissimilar to HBREF (Fig. 18, Table 12). The reference sample was taken at the same time the fall 1999 sample was taken at WB3, WB4, and WB5 so seasonal effects would be minimal when comparing the fall 1999 and fall 2000 samples. WB4 showed the same trend when compared with HBREF; the dissimilarity increased as the pond aged (Fig. 19, Table 13). Dissimilarity between WB5 and HBREF began by showing the expected trend; dissimilarity decreased as the pond got older until the summer 2000 sampling season was reached. Suddenly, the dissimilarity spiked and remained high through the fall

2000 season (Fig. 20). The summer spike could have been caused by a mass emergence of a certain taxa or a disturbance in the pond. Unfortunately, water chemistry data was not provided for the summer 2000 sampling season of WB5 so it is unknown whether or not a water chemistry disturbance occurred. However, aluminum and iron concentrations in the fall 2000 sample are very high and could indicate a disturbance in that season (Table 17).

Habitat differences also play a role in the dissimilarity between the experimental ponds and HBREF. The three experimental ponds are in open areas with little to no overhanging vegetation or macrophytes. Honey Branch (HBREF), however, more closely resembles a wetland environment. There is an abundance of overhanging vegetation, facultative wetland plants such as cattails (*Typha sp.*), and soils that are characteristic of wetland soils. The entire area is more enclosed and shaded.

The Honey Branch site is not part of an active mining operation and is, therefore, no longer disturbed. The experimental ponds are active sedimentation ponds, and because of this, they are routinely treated with calcium hydroxide $(CaOH)_2$ and sodium hydroxide (NaOH) to elevate the pH of the water before it is discharged into the stream. They are also regularly dredged in order to remove excess sedimentation. This activity not only severely disturbs animal communities within the ponds, but also any successional plant communities. In addition, total suspended solids are naturally increased during one of these dredging events or even during a period of rain or excess runoff from the valley fill. Sediment in the ponds is extremely fine and takes a long time to settle.

Another approach to determining whether the younger ponds, WB3 and WB4, are undergoing any successional change is to compare them with the oldest of the three experimental ponds, WB5. This comparison shows, that as WB3 ages, it became slightly less dissimilar to WB5. This trend was broken in summer 2000 and fall 2000 when dissimilarity to WB5 increases again. WB4 does not change in dissimilarity to WB5 until summer, when it increased in dissimilarity with WB5 (Figs. 13 –17 and Tables 7-11). Again, this may be due to a water chemistry disturbance, but without the summer 200 data for both WB4 and WB5, that issue cannot be addressed. Gee et al. (1997) found that there is no significant relationship between pond age and number of taxa living in that pond. Other studies have shown that there are significant changes in benthic communities for the first several years after the construction of ponds, especially in the first and second years (Barnes 1983, Voshell and Simmons, 1984, Krzyzanek et al. 1986). But, these are temporary ponds that are naturally occurring and, therefore, have terrestrial organic matter in the water. Decomposition of this material can support a large community of invertebrates as well as plants. Constructed ponds more than likely have this food source removed during construction. In construction of sedimentation ponds in this study, all woody vegetation was removed prior to construction; after the ponds are created, the areas around them are mulched and revegetated with grasses (Pen Coal Corp., 1997).

Layton and Voshell (1991) found that artificially constructed ponds act differently. In the beginning, these ponds quickly colonize with a few taxa and then species evenness levels off. Perhaps the ponds eventually reach a stasis regarding taxa diversity and then do not significantly change after that. Depending on the habitat availability, water chemistry, and other extrinsic factors, those low-diversity ponds are host to just enough different and unchanging taxa to retain a high degree of dissimilarity.

It must be remembered that ecological succession cannot be determined in a one or even a three-year period. It is also important to acknowledge that the ponds from both of these studies are part of a mining operation and are, therefore, subject to disturbances such as water treatments, runoff events, and dredging. These disturbances can have a profound impact on the benthic communities inhabiting the ponds and can, therefore, mask or even upset any ecological succession that is occurring.

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