Macroinvertebrate diversity and abundance in two experimental wetlands from top-down and bottom-up interpretations

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Abstract

Assessment of a macroinvertebrate community is a tool in investigating the complex food webs of wetlands and the relative contributions of top-down and bottom-up control. In this study, the macroinvertebrate population of the two experimental wetland basins at The Olentangy River Wetland Research Park in Columbus, Ohio, USA, were sampled with Hester-Dendy plates and dipnets. Diversity and evenness were estimated using the Shannon Indices, and compared with indices in previous studies at the same site. For Wetland 1, diversity and evenness were calculated to be 0.98 and 0.47; for Wetland 2, 0.46 and 0.24. Both indices decreased this year from last year, but this may be due to differences in sampling techniques. Gastropoda dominated the total samples of both wetlands, at 83% and 98%, respectively, of the total samples. Wetland 2 had a statistically significantly larger population of macroinvertebrates than Wetland 1. This may be related to recent changes in macrophyte community structure changes that increased periphyton availability in Wetland 2 and the larger number of fish predators in Wetland 1. Other macroinvertebrates sampled were Odonata, Diptera, Crustacea, and Hymenoptera.

Introduction

Some predator-prey relationships are consistently stable. Other relationships fluctuate and always appear to be in a state of imbalance. Determination of the mechanisms of control in each type of system is never easy. When the activities of the predator control the abundance of prey, the situation is known as top-down control (Stiling, 1999). When the abundance of prey determines the activities and abundance of the predator, the situation is known as bottom-up control.

The degree to which either of these situations affects the structure of the wetland food web is still a matter of debate; it has been suggested that their relative contributions vary between individual wetlands (Batzer and Wissinger, 1996). The role invertebrates play in the wetland detrital food web is important to understand this complex web.

Batzer et al. (2000) observed that fish populations directly suppress invertebrate populations and that the overall top-down effect of fish predation is strong. Fish predation alters the structure of zooplankton communities, causing them to shift in their composition to larger individuals, while invertebrate predation causes a shift to smaller individuals (Herwig and Schindler, 1996). It has also been suggested that plants and periphyton compete for the same nutrients and that this competition ultimately determines the amount of periphyton available to invertebrates as a food source (Jones et al., 1999). Since most of the research regarding wetland benthic invertebrates conflicts, further research and interpretation is necessary.

The ease of sampling and identifying invertebrate populations allows some insight into the way these complex communities function. Invertebrates are already used as indicators of environmental change due to their sensitivity to anthropogenic and natural changes (Chessman and McEvoy, 1998). The sheer abundance of invertebrates in any community makes it possible to achieve large sample sizes which are critical for the most accurate monitoring of a system (Hellawell, 1986.)

The differences in macrophyte community structure at the Olentangy River Wetland Research Park permits further investigation into the structure of the wetland food web and the role that macroinvertebrates fulfill within it.

The objectives of this study are:

1. To estimate the diversity of the macroinvertebrate communities of the two experimental wetland basins.
2. To compare the macroinvertebrate communities of each experimental wetland basin.
3. To compare the macroinvertebrate diversity estimated this year with those of previous years' studies.
4. To rationalize the diversity and abundance of macroinvertebrate communities of the two experimental wetlands from bottom-up and top-down approaches.

Methods

Site Description

This study was conducted during October 2001 at the Olentangy River Wetland Research Park, at The Ohio State University in Columbus, Ohio, USA. This 30-acre wetland research facility contains two one-hectare experimental wetland basins that were constructed in 1994. Wetland 1 (referred to as W1 hereafter) was planted with 12 species of typical wetland plants, including *Scripus* sp., *Juncus* sp., and *Schoenoplectus tabernaemontani*, while Wetland 2 (W2) remained an unplanted control

(Mitsch et al., 2001). Water inflow from the proximate Olentangy River is pumped into the wetlands by two pumps, one of which also permits the passage of small fish, invertebrates, and other biota from the river to the wetlands (Cochran, 1998).

Sampling Locations

Samples were collected from the inflow, middle, and outflow regions of the two experimental wetlands (Figure 1). Sampling occurred at three sites in each of these regions. Sampling locations were kept constant with those chosen in previous years to allow comparison of data.

Sampling Design

Hester-Dendy Plate Sampling Method

Hester-Dendy plates were placed at 18 locations in the two wetlands, nine plates total in each wetland basin, in order to quantitatively measure the invertebrate populations of each basin. Three plates were placed at each of the inflow, middle, and outflow regions (Figure 1). Each group of plates was made of nine 8 cm x 8 cm plates that were positioned approximately 0.75 cm apart from one another. The plates were suspended from the boardwalk on October 6, 2001. The plates were left undisturbed and submerged in the water for 15 days. On October 21, 2001, the plates were gently lifted from the water and placed in Ziploc bags for transport. Three plates were not recovered, from W1 middle, W1 outflow, and W2 middle. The samples were immediately transported to the laboratory, where the plates were washed with 70% ethyl alcohol. The samples were stored in bottles containing 70% ethyl alcohol for later identification.

Dipnet Sampling Method

Dipnet sampling was used to qualitatively measure the invertebrate populations of the two wetlands. The dipnet used had a net with mesh size 8x 8 cm. Dipnet sampling occurred on October 21, 2001. The dipnets were placed in the water, net perpendicular to but not touching the sediments, and swept forward for approximately four meters, taking care to avoid trapping vegetation in the net. This process was repeated four times in each wetland basin. Samples were sorted on site and placed into 70% ethyl alcohol for later identification.

Data Analysis

Identification of Samples

Samples were counted and identified to the lowest possible taxonomic level using Pennak (1978) and Merrit and Cummins (1996). Significant differences between the invertebrate populations of the two wetlands were evaluated using the t-test, with confidence set at 95% (a=0.05).

Calculation of Shannon Indices

The Shannon index for diversity is a commonly used method of measuring species diversity (Stiling, 1999). It assumes that all species from the community are represented in a randomly collected sample. The formula is:

$$H' = -S\, p_i \ln (p_i)$$

where p is the proportion of individuals in the ith species. Error arises from not including all species of the community in the sample. As the number of species represented increases, error is reduced. Typical Shannon diversity index values fall between 1.5 and 3.5.

The actual diversity of a community can be compared to its maximum diversity by determining species evenness. This formula is:

$$J = H'/ H_{max} = H'/ \ln (s)$$

where H_{max} is the maximum diversity and s is the total number of species. Values for J fall between 0 and 1, and indicate how evenly the species are spread throughout the system (Stiling, 1999). Both the Shannon indices for diversity and evenness were calculated for the macroinvertebrate populations sampled in the two wetlands.

Results and Discussion

Summary and Comparison of Macroinvertebrate Communities

A total of 510 macroinvertebrates were collected by the Hester-Dendy plates and dipnet sampling methods. These organisms were identified to the lowest possible taxonomic level. All organisms were identified to

Figure 1. Diagram of Wetland 1 and Wetland 2 at the Olentangy River Wetland Research Park. The placement of Hester-Dendy plates is indicated by HD. Dipnet sampling occurred at places indicated by DN.

the genus level, with the exceptions of one organism in the class Crustacea and one organism in the class Hymenoptera. One organism could not be identified. The organisms collected represent four classes, seven orders, nine families, and six genuses (Table 1). The samples collected by the Dipnet sampling method were used to qualitatively assess the macroinvertebrate population, while the samples collected by the Hester-Dendy plates were used to quantitatively measure the macroinvertebrate population. Table 1 summarizes the macroinvertebrate diversity from 1994-2001 (continued after Acharyya and Mitsch, 2000).

Three of the Hester-Dendy plates were not retrieved from their initial boardwalk placement or the surrounding sediment after the 15-day colonization period. The location of these plates could not determined. One of the sets of plates was from W1 outflow, another was from W1 middle, and the third was from W2 middle. It is not possible to predict the true impact of these lost samples on this study, but it is safe to assume that the number and diversity of organisms at these three stations is underrepresented.

The total number of specimens collected in W1 was 176; 95 of these were collected by the Hester-Dendy plates. The total number of specimens collected from W2 was 334; 206 of these were collected by the Hester-Dendy plates. The majority of the recovered macroinvertebrate samples were members of the class Gastropoda. In W1, members of this class constituted 83% of the total sample. In W2, this proportion was even higher at 98% of the total sample. More insects were sampled in W1 than W2, with 14.7% of the samples in W1 and 0.97% of the samples in W2 members of the class Insecta. The remaining samples in W1 were 1% Crustacea and 1% unidentified; in W2 they were 0.97% Crustacea and 0.97% Hymenoptera. There was a significant difference in macroinvertebrate abundance between the W1 and W2 ($t=3.296$, $p=0.0011$).

The most apparent difference between the samples of the two basins was the number of Gastropoda collected in each. A total of 202 Gastropods were collected in W2; 90.6% were genus *Physa*, 8.4% were *Lymnaea*, and slightly less than 1% was *Helisoma*. In W1, 79 Gastropods were collected; 88.6% were genus *Physa*, 3.8% were *Lymnaea*, and 7.6% were *Helisoma*. These numbers vary significantly from previous years; in 2000, the numbers of Gastropoda collected from the two basins were more similar (Acharyya and Mitsch, 2001). In 1999, it was first noted that the invertebrate communities were beginning to diverge (Frazier and Mitsch, 1999). In 1998, there were no statistical differences between the two invertebrate communities (Lowry, 1999).

Table 3 compares the Shannon indices for richness and diversity from 1997 to 2001. It is important to recognize that the Shannon indices were intended for use in situations where organisms were identified to the species level; it also assumes that all species present in the community are represented in the sample (Stiling, 1999). In this study, none of the specimens were identified to the species level, only the genus level at best, and the very low number of taxa present is a good indication that not all species in the community are represented in the sample. In addition, the data presented in this study must be viewed conservatively due to the loss of the three Hester-Dendy plates. Even though their utility in this situation is limited, the Shannon indices for diversity and evenness were nevertheless calculated and a comparison attempted.

The Shannon indices for species diversity and evenness for both wetlands decreased significantly for 2000. In W1, species diversity was calculated to be 0.98 and evenness was calculated to be 0.47, falling from 1.56 and 0.98 from

Table 1. Macroinvertebrate abundance and taxonomic richness at three sites in Olentangy River Research experimental wetlands 1 and 2 (October 2001)

CLASS	ORDER	FAMILY	GENUS	WETLAND 1				WETLAND 2			
				IN[a]	MI[a]	OUT[a]	DN[b]	IN[a]	MI[a]	OUT[a]	DN[b]
Crustacea	Amphipoda			0	0	1		1	0	0	
Gastropoda	Basomatophora	Lymnaeidae	Lymnaea	1	1	1	X	7	1	9	X
Gastropoda	Basomatophora	Physidae	Physa	45	17	8	X	100	54	29	X
Gastropoda	Pulmonata	Planorbidae	Helisoma	4	1	1	X	2	0	0	X
Insecta	Coleoptera	Haliplidae	Peltodytes	1	0	0	X	0	0	0	
Insecta	Diptera	Chironomidae	Chironomus	2	0	0	X	1	0	0	
Insecta	Diptera	Nematocera		0	0	0	X	0	0	0	
Insecta	Hempitera	Corixidae		0	0	0	X	0	0	0	X
Insecta	Odonata	Anisoptera		0	0	0		0	0	0	X
Insecta	Odonata	Lestidae	Lestes	7	2	2		0	1	0	X
Hymenoptera				0	0	0		0	0	1	
Unidentified				1	0	0		0	0	0	

[a]. Inflow, middle, and outflow sites sampled with Hester-Dendy plates
[b]. Samples collected with dipnets and used for qualitative assesment

Table 2. Survey of nacroinvertebrate diversity from 1994 - 2001 at ORWRP experimental wetlands

	1994	1995	1996	1997A	1997B	1998	1999	2000	2001
Crustacea		X	X	X	X		X	X	X
Gastropoda	X	X	X	X	X	X	X	X	X
Hirudinea						X	X	X	
Hymenoptera									X
Insecta	X	X	X	X	X	X	X	X	X
Oligochaeta						X	X	X	
Pelecypoda						X	X	X	
ORDERS									
Amphipoda					X			X	X
Arhynchobdelia						X	X	X	
Basomatophora	X	X	X	X	X			X	X
Cladocera		X	X	X				X	
Coleoptera	X	X	X		X	X	X	X	X
Collembola			X						
Diptera	X	X	X		X	X	X	X	X
Ephemeroptera	X	X	X			X		X	
Hemiptera	X	X	X		X	X		X	X
Homoptera			X						
Hydracarina		X							
Maxillipoda		X							
Neuroptera					X				
Odonota	X	X	X		X	X	X		X
Opisthopora		X							
Orconectes					X				
Platyhelminthes								X	
Plesiopora		X							
Pulmonata		X						X	X
Tricladida		X							
Trichoptera	X		X		X				

Table 3. Comparison of Shannon indices for macroinvertebrate diversity at ORWRP experimental wetlands

SITE/METHOD	Speiles (1997)	Custer et al. (1998)	Lowry (1998)	Frazier (1999)	Acharyya et al. (2000)	Current study (2001)
HESTER-DENDY						
Wetland 1	H[a]=1.49 J[b]=0.65	H=1.06 J=0.46	H=0.76 J=0.50	H=0.70 J=0.36	H=1.56 J=0.56	H=0.98 J=0.47
Wetland 2	H=1.56 J=0.68	H=1.25 J=0.57	H=0.78 J=0.53	H=1.23 J=0.76	H=0.96 J=0.35	H=0.46 J=0.24
FUNNEL TRAPS						
Wetland 1				H=0.78 J=0.56 H=1.02 J=0.74		
Wetland 2				H=1.23 J=0.79 H=0.46 J=0.29		
BOTTLE TRAPS						
Wetland 1					H=1.2 J=0.43	
Wetland 2					H=1.3 J=0.47	

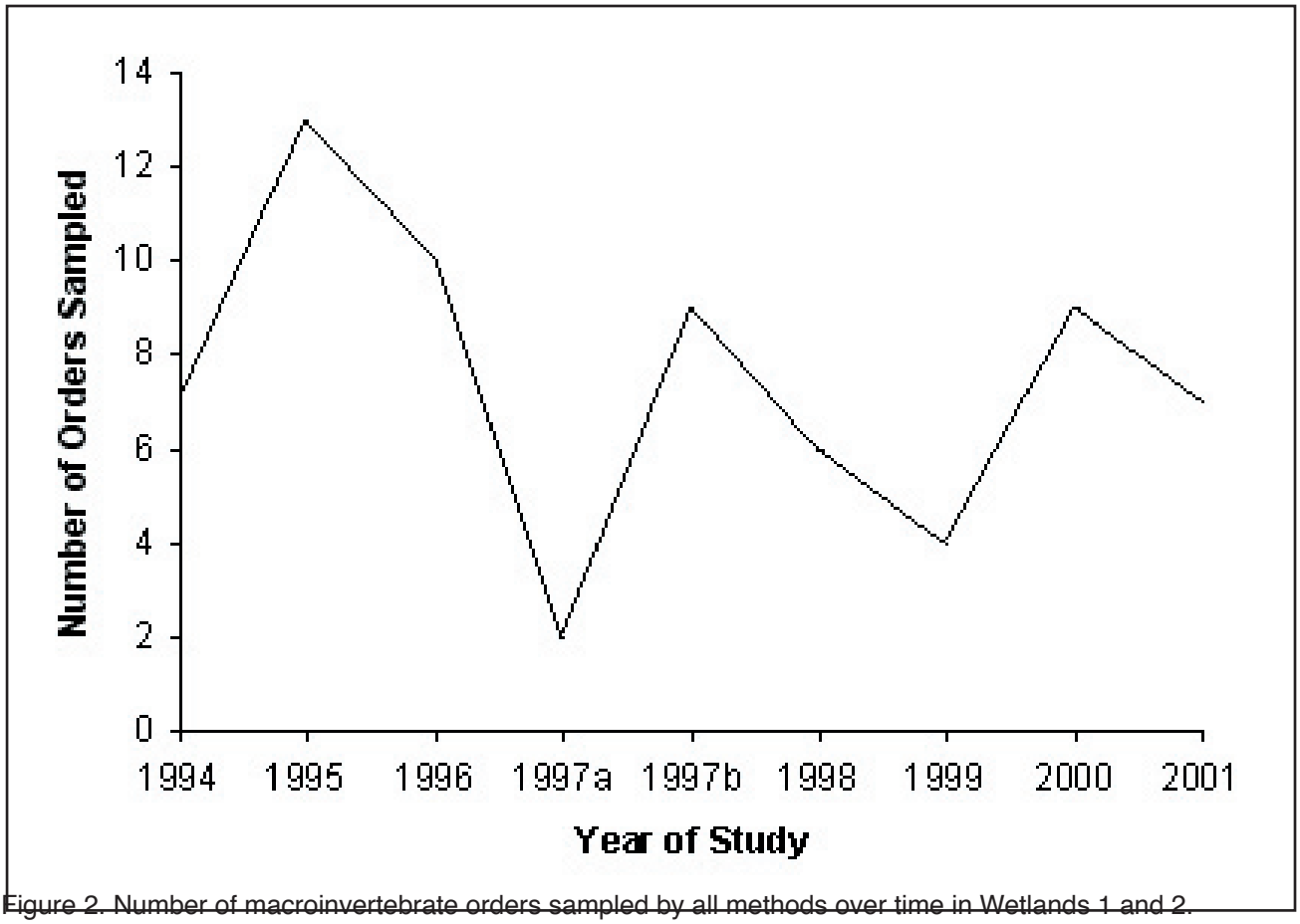

Figure 2. Number of macroinvertebrate orders sampled by all methods over time in Wetlands 1 and 2.

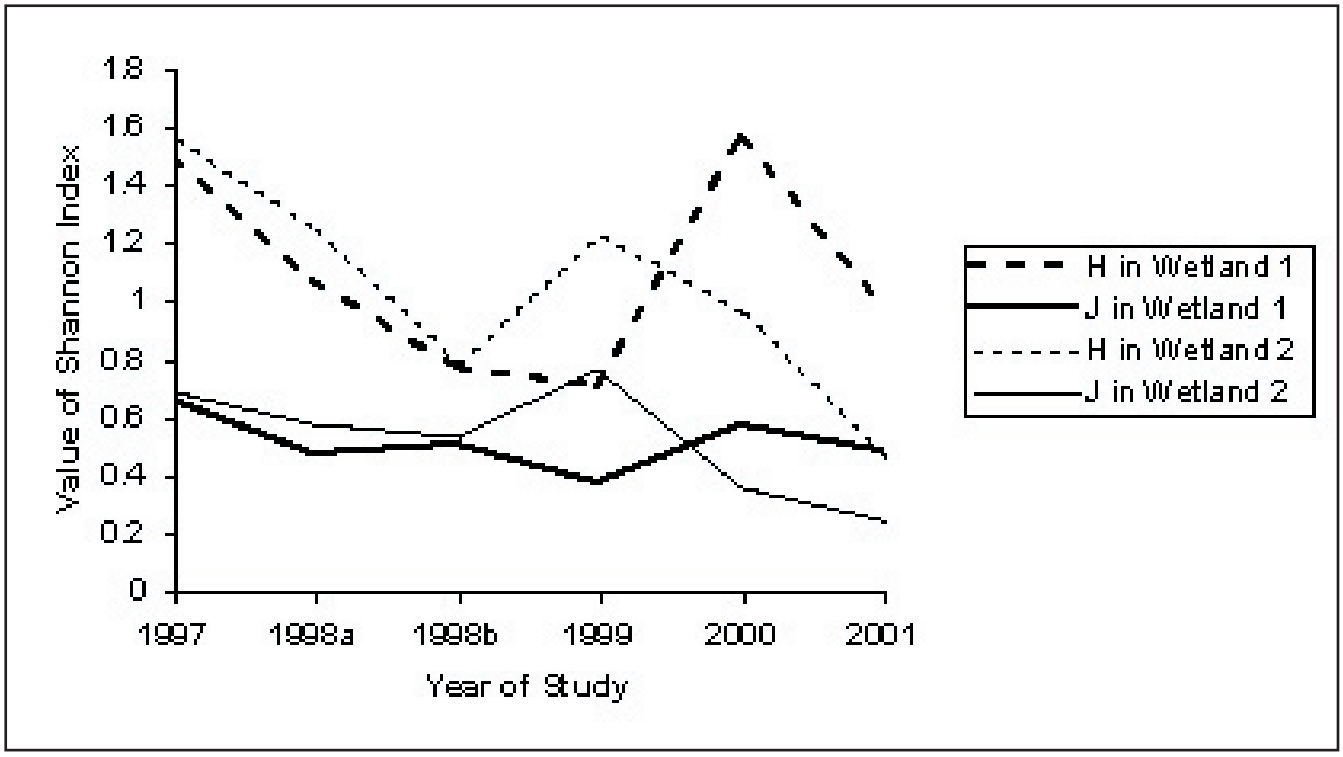

Figure 3. Changes in Shannon Indices for diversity and evenness in Wetland 1 and Wetland 2 over time.

the previous year (Acharyya and Mitsch, 2001). In W2, species diversity was calculated to be 0.46 and evenness was calculated to be 0.24, falling from 0.96 and 0.35 from the previous year (Acharyya and Mitsch, 2001).

The large number of Gastropoda collected in this study was expected after reviewing the studies from previous years. What was unexpected was the low representation of other taxa, both in diversity and abundance. Unexpected absences from both basins included Oligochaeta, Pelecypoda, Arhynchobdellia, and Ephemeropera, which have been frequently represented in previous studies (Table 2). These absences may be due to the sampling methods used in this study. In 2000, bottle traps were employed in addition to the Hester-Dendy plate and dipnet sampling methods (Acharyya et al., 2000). In this study, only the dipnet and Hester-Dendy plate method were used. It is recommended that any similar studies performed in the future also make use of the bottle trap method in order to increase the number and diversity of samples.

Macroinvertebrate Community Structure: Bottom-Up Interpretation

One of the most significant differences between the two experimental wetland basins lies in the structure of their macrophyte communities. In 1994, W1 was planted with typical wetland plants, while W2 remained an unplanted control, but over time the percent macrophyte cover in each basin became increasingly similar. (Mitsch et al., 2001). In 1999, W2 was dominated by *Typha* sp., while W1 remained more diverse through the codominance of 3-4 of the originally planted species. During the winter of 2000, *Ondatra zibethicus*, commonly known as muskrats, moved into W2 and have altered the macrophyte structure of that basin (Mitsch et al., 2001). Muskrats preferred W2 because of the abundance and nutritional value of *Typha* (Higgins and Mitsch, 2001). A visual inspection of W2 on October 30, 2001, verified that W2 had been nearly cleared of its vegetation; it now appears to have a much smaller percent cover than W1.

The amounts of periphyton production and aquatic plant life coexisting in a water body are closely related. In addition to a high nutrient intake that can limit plant growth, periphyton shield light from and reduce carbon availability to aquatic plants (Sand-Jensen, 1977). High amounts of both periphyton and aquatic plant life rarely coexist because they make similar nutrient demands on the water. Periphyton is a complex community of bacteria, algae, and detritus that is an important food part of the macroinvertebrate, and specifically Gastropod, diet. Jones et al. (1999) that Gastropods will remove between 67-85% of the algae population in a small body of water. The recent clearing of vegetation in W2 by muskrats may have reduced both macrophyte demand upon the water and shading, subsequently permitted periphyton abundance to increase. A larger food base for Gastropods will result in an increase in their population. The larger macrophyte community in W1 may mean a smaller periphyton community, due to fewer available nutrients and shading, and a smaller population of Gastropods.

Thomas suggested in 1990 that a system of mutualistic dependencies exists between aquatic plants and periphyton-grazing Gastropoda, with periphyton a critical link between the two. When these groups exist in the same community for an extended time, the plants benefit by a reduced periphyton competition, while the Gastropods benefit nutritionally and by increased habitat and protection from predators. Jones et al. determined in 1999 that plants are more likely to survive in the presence of Gastropods. The larger population of Gastropods in W2 can be interpreted as an indication that this system of mutualism may have been disrupted when the vegetation was cleared by muskrats. It is possible to consider W1 as an example of this system of mutualistic dependencies at work.

The numbers of Gastropods sampled in both W1 and W2 were highest at the inflow, lowest at the outflow, and intermediate at the middle sites (Table 1). Even when the Gastropod populations sampled at W1 middle, W1 outflow, and W2 middle are increased by 50%, in an attempt to adjust for the unrecovered Hester-Dendy plates, this trend remains apparent. This trend is most evident for Physidaeard, Gastropoda that occurred most frequently at all sites in both basins. The river-fed basins are both highest in nitrate-nitrogen and total phosphorus concentrations at the inflows, lowest at the outflows, and intermediate in the middle. The increased availability of nutrients will increase primary production of photosynthetic periphyton, and increase invertebrate abundance (Batzer and Wissinger, 1996). An even abundance of Gastropoda throughout the basins was therefore not be expected. The larger numbers of Gastropoda found at the inflows may be reflective of the higher nutrient availability found there, and Gastropoda abundance decreased with nutrient availability. On the contrary, low amounts of dissolved oxygen (DO) is a frequently observed limit to invertebrate growth, and both basins exhibit the lowest DO at the inflows and highest DO at the outflows (Spieles and Mitsch, 2000; Mitsch et al., 2001). In this situation, DO did not appear to be a limiting factor for invertebrate growth.

Macroinvertebrate Community Structure: Top-Down Interpretation

In addition to a decreased food availability, another reason the Gastropoda population in W1 is smaller was the larger number of predators that occur there. *Lepomis cyanellus*, commonly known as green sunfish, have dominated the fish populations of both basins since 1996, and the observed population of green sunfish in 2000 was higher in W1 by a factor of nearly 5.7 (Kleber et al., 2001). Gastropoda populations, specifically Physidae, are suppressed in the presence of fish (Batzer et al., 2000).

This large community of predators in W1 will severely limit the macroinvertebrate population in that basin and may be why fewer Gastropods were sampled there.

Gastropoda population levels will also influence the population levels of other invertebrates. In the absence of predation by fish, Gastropoda populations will increase to sizes that will suppress the populations of other invertebrates (Batzer et al., 2000). The large population of Gastropoda in W2 may be suppressing the population of other invertebrates in the ecosystem. The Shannon indices calculated in 2000 and for this study both indicate that the macroinvertebrate population in W2 is less diverse than that of W1. However, the results presented in this study should not be considered as sole support for this phenomenon. The diversity and abundance of macroinvertebrates other than Gastropoda may not be representative of the true situation due to the sampling methods used here. Perhaps future studies will be more meticulous and be able to give credence to this idea.

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