Macroinvertebrate abundance and richness in two constructed wetland systems

Michelle L. Lowry

School of Natural Resources
The Ohio State University

Introduction

Definitions of wetlands do not currently include parameters for fauna (Mitsch and Gosselink, 1993), however, many organisms, such as benthic invertebrates, have strict habitat requirements based on life history stages (Pennak, 1953) such that their presence, taxonomic diversity, and abundance may provide a supplementary character for assessment much in the way that flora does. Nevertheless, these measures do offer information on the habitat type and quality (specifically the water quality of a particular system), as different taxa tolerate or require different environmental factors, both biotic and abiotic (Spieles, 1998). For instance, members of Class Gastropoda (snails) and Class Pelecypoda (freshwater clams) generally require hard waters high in carbonates (alkaline systems) and dissolved oxygen. Members of Order Amphipoda (scuds) and Order Odonata (dragonflies and damselflies) are found widely distributed in unpolluted waters. Mayfly nymphs (of the order Ephemeroptera) occur wherever there is an abundance of dissolved oxygen. Conversely, annelids of the class Oligochaeta (aquatic earthworms) can tolerate low concentrations of dissolved oxygen while annelids of the class Hirudinea (leeches) can thrive in polluted waters (Pennak, 1953). Based on these requirements, the Ohio EPA has historically used taxonomic presence/absence, abundance, and richness as indicators of stream water quality (Krieger, pers comm.). There is evidence that similar quality assessments could be devised for wetlands (Hart et al., 1997).

Macroinvertebrates function in trophic webs as a food base for many other taxa. Fish predation is especially important as wetlands have long been noted as fish nurseries (Murphy and Willis, 1996). These benthic invertebrates are an especially important prey base during the summer months when zooplankton populations decline (Wetzel, 1983). Wetland invertebrates are also preyed upon by amphibians (Cochran, 1996), dabbling ducks, muskrats (Meffe and Carroll, 1994), and even other invertebrates. Pennak (1953) noted that leeches prey upon oligochaetes, amphipods, and chironomid larvae.

Valuable information can be gained from knowing the community structure of macroinvertebrates; however, there are problems inherent in conducting studies of abundance and richness. Heterogenous substrate affects dispersion (Wetzel, 1983), producing clumped, rather than random distributions (Murphy and Willis, 1996). Temperature, food availability, life histories, and predation pressures also play a role (Wetzel, 1983). These factors are compounded by inadequacies of particular gear types. D-frame aquatic nets (dip nets) are good for collecting quantitative data of richness and abundance, and for statistically evaluating precision; however, care has to be exercised on sampling the same amount of area or time repetitively. Colonization plates reduce variation among sampling units in similar areas and are good for studies of water quality; however, information obtained is not sufficient for studies of richness, relative species abundances, or biomass (Murphy and Willis, 1996).

Historical data documenting changes over time are particularly important in the study of constructed wetlands because of issues of mitigation (Mitsch and Gosselink, 1993). Metzker (1995) notes that functional integrity in these systems is obtained partly through a diverse and productive macroinvertebrate community, while Hart et al. (1997) mention that aquatic invertebrates may be indicators of wetland maturity. This study attempts to document richness and abundance in two constructed wetlands (planted and unplanted) and to document changing trends through time.

Methods

Data Collection

Macroinvertebrates at the Olentangy River Wetlands (ORW) were collected from 15- 31 October 1998. Nine sampling stations (three per basin) were established for each of the two 1-ha constructed wetlands (Fig. 1). Three sampling methods were used: Hester-Dendy plates placed at all nine stations in each wetland, bottle traps placed in the middle of each basin (a total of three traps per wetland), and dip-net collection at three locations (one in each basin).

Hester-Dendy plates (approximately 11 cm^2 in area) were placed along an east-west gradient in each basin. Two plates were along the outer edges and one was in the middle, in the deepest portion of the basin. Plates were submerged for the duration of collection. They were removed on 31 October, at which time they were carefully lifted and placed immediately onto a plate. Specimens were removed manually with forceps and placed into 70% ethyl alcohol in labeled vials.

Bottle traps (two liters in volume) were submerged in the middle of each basin. Traps were emptied every two days.

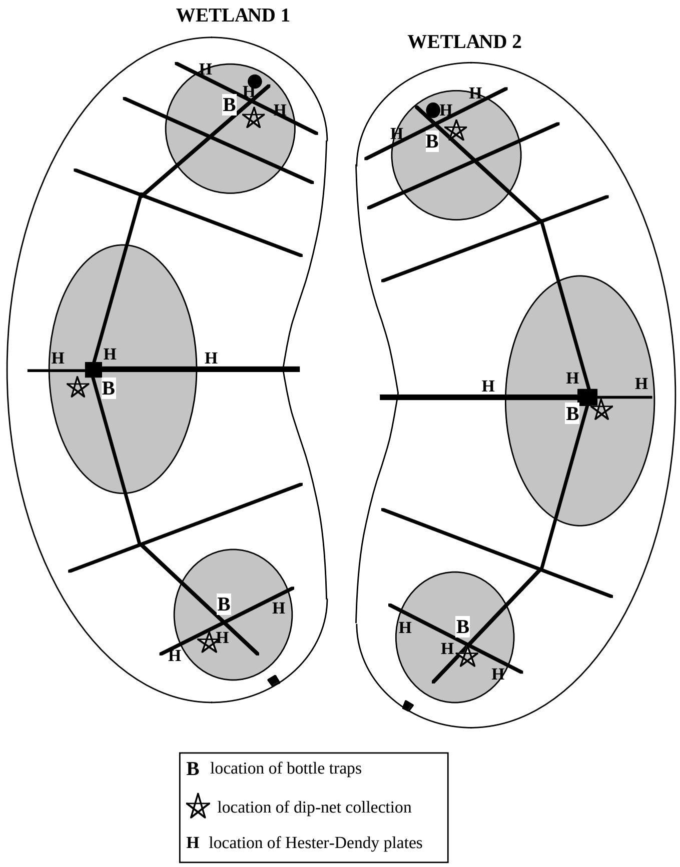

Figure 1. Location of trap sites at the Olentangy River Wetlands

Samples were poured into a pan (35 cm x 19.5 cm). Invertebrates were removed manually with forceps and preserved in 70% ethanol. Vertebrates (bullfrog tadpoles) were returned to the wetland.

Dip net collections (one sweep per basin) were performed on the days the bottle traps were emptied. Collections were made moving east from the middle of the basin, covering an approximate area of 2 meters. The dip net (0.595 mm mesh size) was run across the surface of the sediment to collect invertebrates that were either on the surface or partially submerged.

Sediment collected was placed in the pan described above and invertebrates were preserved in labeled vials containing 70% ethanol.

Invertebrates were sorted in the laboratory by lowest recognizable taxa, usually order, but in some cases, class. Aquatic insects and nymphs were identified to order using Merrit and Cummins (1978).

Data Analysis

Numbers of organisms collected by each trap type at each site were pooled to find the total number collected per wetland and a Student's t-test was run to determine if there was a significant difference. Taxa found were counted to determine richness. Numbers of organisms collected each day at each wetland were pooled and plotted against days of inundation (beginning with the first day that samples were taken after water was pumped into the previously dry wetlands) to detect any noticeable trends. Historical numbers for each taxa were calculated as percentages of the total for comparisons across years. A population estimate for snails was performed by finding the average number of individuals per Hester-Dendy plate for each site and dividing this number by the area available for colonization on the plate (0.0605 m^2), giving the average number of individuals per square meter. An average for each wetland was found and this number was divided by 0.0001 to find the average number of snails ha^{-1} (1 m^2= 0.0001 ha).

Results

A total of 1355 benthic invertebrates were collected during this study, with 699 invertebrates representing 10 taxa collected in Wetland 1 (referred to as W1 hereafter) and 656 specimens of nine taxa collected in Wetland 2 (referred to as W2 hereafter) (Table 1). The relative abundance of taxa for the two wetlands is shown in Figure 2. Statistical analysis by Student's t-test showed no significant difference between abundances in W1 and W2 (=.05, P= 0.48). Both collections were dominated by snails, with 79.8% (1081

Table 1. Invertebrate abundance and taxonomic richness in the two constructed wetlands (October 1998)

Taxa	Wet 1	Wet 2
Phylum Mollusca		
Class Gastropoda	563	518
Class Pelecypoda	2	22
Phylum Annelida		
Class Oligochaeta	2	
Class Hirudinea	2	1
Phylum Arthropoda		
Class Malocostraca		
Order Amphipoda	62	19
Class Insecta		
Order Ephemeroptera	2	6
Order Odonata	2	5
Order Hemiptera	0	5
Order Coleoptera	32	29
Order Diptera	32	50
Unknown	1	
Abundance	699	656
Taxonomic Richness	10	9

individuals) of all specimens being members of the class Gastropoda (80.5% or 563 individuals from W1 and 79.0% or 518 individuals from W2) (Table 2). Amphipods were the next most abundant in W1, with 8.90% of the total (62 specimens), whereas dipterans comprised 7.6% of the total in W2 (50 specimens). All other taxa combined accounted for less than 15% of the totals in each wetland. The major differences in abundances between W1 and W2 were found in Pelecypoda (2 organisms in W1, 22 in W2), Amphipoda (62 organisms in W1, 19 in W2), and Diptera (32 organisms in W1, 50 in W2) (Table 1).

As shown in Table 3, all taxa found in 1994 were unique, as this marked the first year of the benthic invertebrate community in the ORW. In 1995, Cladocera, Hydracarina, Maxillopoda, Opisthopora, Pleisiopora, Pulmonata, and Trichladida were all found for the first time. Two new orders were found in 1996 (Orconectes and Platyhelminthes). Spieles (1998) noted the first occurrence of Arhynchobdellia in 1977. Three taxa (Amphipoda, Hirudinea, and Pelecypoda) were noted for the first time in this study while other commonly found taxa were not collected (Cladocera, because they were not sample for, and Trichoptera). Taxonomic richness (Table 3), using class and order as levels of classification, was found to be 7 in 1994, 13 in 1995, 10 in 1996, 12 in 1997 (using the average number found by Spieles 1997 and Hart et al., 1997), and 10 in 1998, giving an average across the years of 10 taxa.

Population estimates conducted for Gastropoda in 1998

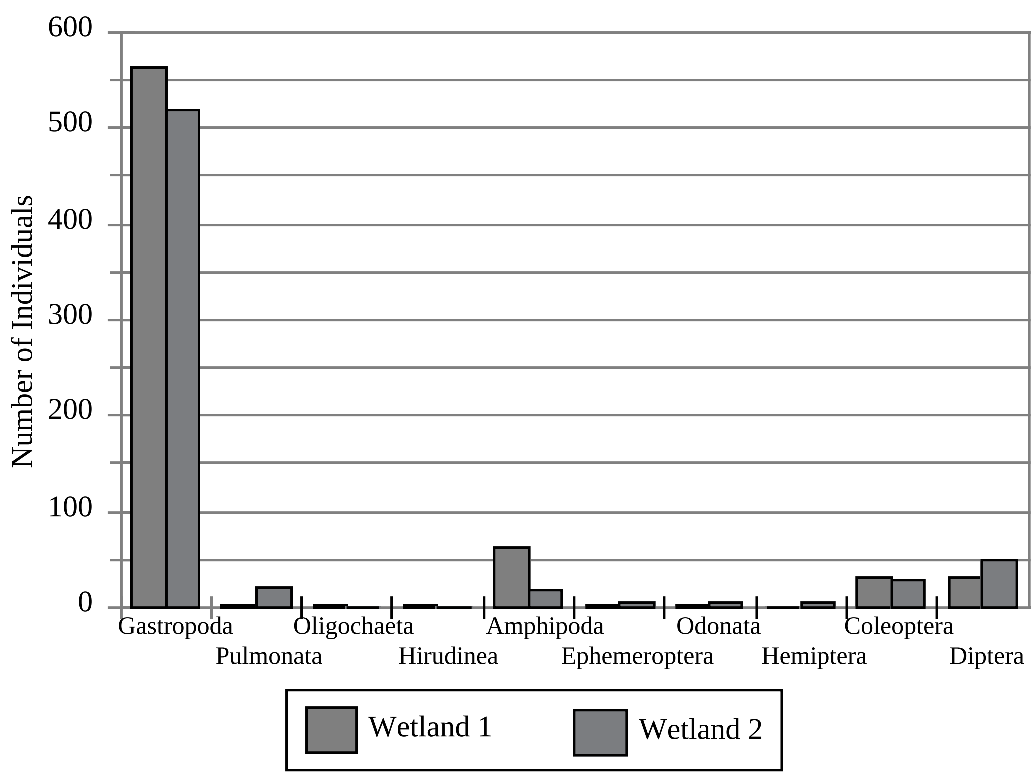

Figure 2. Abundance of macroinvertebrates in 1998 sampling by taxa

Table 2. Percent composition of taxa at the Olentangy River Wetlands collected in 1998

	W1	W2
Amphipoda	8.90	2.90
Oligochaeta	0.18	--
Hirudinea	0.18	0.16
Gastropoda	80.50	79.00
Pelecypoda	0.18	3.32
Ephemeroptera	0.18	0.91
Odonata	0.18	0.77
Hemiptera		0.77
Coleoptera	4.60	4.57
Diptera	4.60	7.60
Unknown	0.50	--

(Table 4) suggest that W1 contains an average of about $1.7 \times 10^6 \pm 1.6 \times 10^6$ snails ha^{-1}. Similarly, estimates for W2 suggest that total numbers of snails are around $1.1 \times 10^6 \pm 1.0 \times 10^6$ individuals ha^{-1}. Summing these, a total number of 2.7×10^6 snails may be expected in the two experimental wetlands at the ORWRP at any given time.

Plotting the number of benthic invertebrates found against days of inundation, a similar trend was noted for both W1 and W2, with the only major difference in numbers (that is, an increase in one wetland combined with a decrease in the other) occurring after day 14 (Fig. 3).

A steady increase was noted until day 10, when collections fell from 117 and 102 individuals in W1 and W2, respectively, to 46 and 59. Numbers of organisms then increased to 82 and 142 in W1 and W2 respectively until day 14, when numbers found in W1 increased to 99, while those in W2 decreased to 130. On day 16, 142 invertebrates were collected in W1, whereas only 84 were found in W2. Trends were reversed on day 18, when numbers for W1 dropped to 37 and those for W2 rose to 167. Summing both locations produced a visible increase from day 0 to day 8, a decline at day 10, an increase through day 14, then a decrease through the end of sampling

Discussion

Statistical tests showed that after 5 years, the abundances within benthic communities at the ORW are not significantly different. Because one wetland (W1) is planted and one (W2) is not, this would suggest that both habitats, through the process of succession, have become similar enough to support equal amounts of macroinvertebrates (in numbers, not biomass). Different abundances of different taxa indicate that habitat heterogeneity is an issue. Differing amounts of different taxa of aquatic vegetation probably provide the most variation (W1 has large amounts of *Schoenoplectus tabernaemontani*, while W2 supports many *Typha* plants), although no formal studies were conducted.

Richness was shown to be relatively constant throughout time, although new taxa were added and total numbers of taxa increased slightly (from 7 to 13) as the wetlands matured. This trend may be related to a change in aquatic vegetation; however, a change in water quality through time is the likely reason. The presence of large numbers of organisms requiring unpolluted waters high in dissolved oxygen and dissolved salts (especially carbonate) suggests that, since their creation, the quality of water in both wetlands has been improving. Abundances, richness, and taxonomic composition are a property of pumping water into the system, as noted by Cochran (1998); however, the fact that so many organisms survive once in that system gives support to the idea of improved water quality.

Being able to track data through time has many applications, especially in the construction of wetlands. To date, a good record of invertebrate community structure, abundance, and richness has been kept at the ORW (Nairn et al., 1995; Metzker, 1996; Hart et al., 1997; Cochran, 1998; Spieles, 1998). Even so, there are complications that prevent a direct comparison between years. Most studies were conducted within the same approximate time frame (late summer through early fall); however, because of changing life histories of the organisms (and the distribution trends that accompany them), even a difference of a few days could lead to faulty comparisons. When comparing abundances, percents of the total were used to even the affects of differing sampling regimes in every study; however, it still remains that when sampling efforts are increased, the probability of capturing something unique is greater (Murphy and Willis, 1996). Therefore, it may be expected that data from studies with longer sampling periods would exhibit higher richness even if relative abundances remained unchanged. That trend is not accurate when applied to ORW research. The shortest sampling period (Nairn et al., 1995) did produce the least amount of taxonomic richness; however, the highest richness level was achieved by the second shortest sampling period and the longest sampling effort achieved only the second highest level of richness. A more probable explanation is a difference in sampling efforts within the sampling periods. For example, this study used three gear types whereas previous studies used only one.

Another explanation of the differences observed is a feature of the level of taxonomic identification involved. Identification to species would be optimum for these studies; however, owing to the variety of taxa and the large numbers of life history stages, this is widely impractical (Wetzel, 1983). Because of this, many indices, such as the Shannon-Weaver, should not be performed unless modified to fit the taxonomic level recorded, and even so, cross-comparisons would be remain difficult, as less knowledge is achieved when the level of identification increases.

There is a possibility that the removal of organisms at the start of the study may lower the number of organisms available for capture at the end of the study, thus producing misleading results (Murphy and Willis, 1996). This idea was examined using the plot of individuals sampled versus number of days inundated (Fig. 3). No statistical tests were performed; nonetheless, levels of invertebrates taken appear

Table 3. Benthic invertebrate taxonomic richness (by class and order) over time in ORWRP experimental wetlands.

	1994 (Nairn et al. 1995)	1995 (Metzker 1996)	1996 (Hart et al. 1997)	1997 (Cochran 1998)	1997 (Spieles 1998)	(this study)
CLASSES						
Gastropoda						X
Hirudinea						X
Oligochaeta						X
Pelecypoda						X
ORDERS						
Amphipoda						X
Arhynchobdellia					X	
Basomatophora	X	X	X	X	X	
Cladocera		X	X			
Coleoptera	X	X	X	X	X	X
Collembola			X			
Diptera	X	X	X	X	X	X
Ephemeroptera	X	X	X		X	X
Hemiptera	X	X	X	X	X	X
Homoptera			X			
Hydracarina		X				
Maxillopoda		X				
Neuroptera					X	
Odonata	X	X	X	X	X	X
Opisthopora		X				
Orconectes				X		
Neuroptera				X		
Platyhelminthes					X	
Pleisiopora		X			X	
Pulmonata		X			X	
Trichladida		X				
Trichoptera	X		X	X	X	
TOTAL RICHNESS	7	13	10	8	12	10

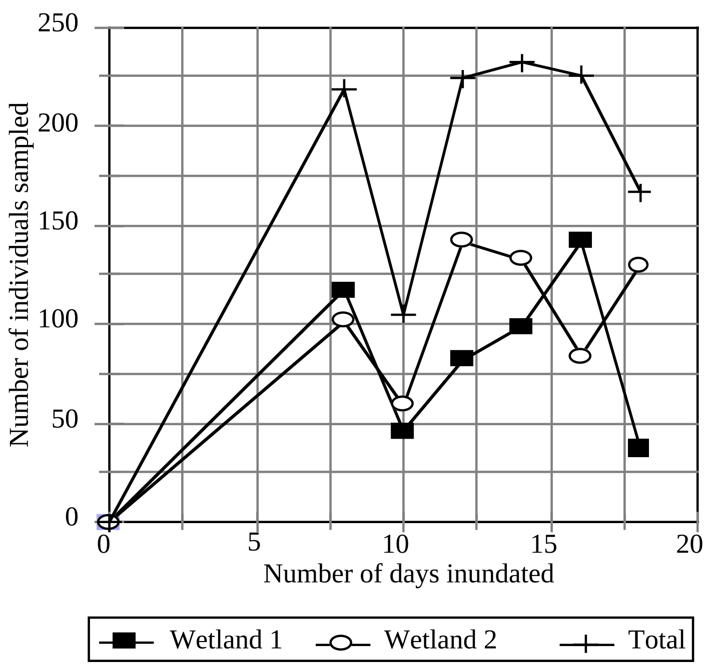

Figure 3. Number of individuals sampled by number of days inundated (day 0 being the first day the wetlands were filled with pumped water and day 18 being the last day invertebrates were sampled).

to fluctuate independently of the amount removed on the first few days. This was expected based on the fact that benthic invertebrates are rudimentary species (r-selective species) that have short life spans and reproduce quickly (Stiling, 1996).

Following the line series for total individuals sampled (Fig. 3), the decline noted at day 10 seems suspect. One possible explanation here is that there were differences owing to pumping. There is also a chance that it was created not by some fluctuation within the system, but instead by a lack of sampling conformity on that day. If that holds true, then the general trend for invertebrates within both W1 and W2 is to increase as a function of days of inundation until about the fourteenth day, at which time levels drop off, possibly due to extreme competition for resources. More repetitions of this procedure would be required for statistical support.

Historically, gastropods and dipterans have contributed greatly to the percent compositions of invertebrates at the ORWRP experimental wetlands. Both serve as an important prey for fish species (such as sunfishes) that characteristically inhabit the wetlands. Assuming that the calculated population estimate for gastropods in Table 4 is accurate, it seems a tremendous prey base is available for these fish, more so in W1 than in W2. It is possible that the calculations for the estimate were faulty, or that projected numbers were too large owing to sampling in areas of high gastropod abundance. Also, numbers may be high if gastropods were selectively attracted to the Hester-Dendy plates for reasons of protection or resources. A more accurate assessment of prey availability should be conducted using biomass (because it gives more information on secondary productivity as it relates to a fish's access to prey) if interest in invertebrates is primarily based on food for fish. (Murphy and Willis, 1996).

Because of their strict habitat requirements, certain taxa of benthic invertebrates are good indicators of water quality. Future work may wish to focus on the possibility of using invertebrates as predictors of water quality in wetlands. A possibility exists for characterizing wetlands based on the community structure, abundance, and diversity exhibited by these organisms.

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Table 4. Population estimate for Gastropoda in each experimental wetland at the ORWRP..

Wet land	# of Hester Dendy plates	# of snails	Snails/ plate	Snails/ m^2	Snails/ ha
1	3	22	7.33	121.16	1,211,600
1	3	29	9.67	159.83	1,598,300
1	2	27	13.50	223.14	2,231,404
ave.±std dev.				168.0±161.3	
2	2	9	4.50	74.38	743,800
2	3	39	13.00	214.88	2,148,800
2	3	5	1.67	27.60	276,000
ave.±std dev.				105.6 ± 97.5	

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