Technical Memorandum No.1

CHARACTERIZATION OF THE MACROINVERTEBRATE COMMUNITY

CHICAGO AREA WATERWAY SYSTEM

HABITAT RESTORATION EVALUATION AND IMPROVEMENT STUDY

Prepared by

Baetis Environmental Services, Inc.

Chicago, Illinois

For

LimnoTech, Inc.

Ann Arbor, Michigan

In support of

Metropolitan Water Reclamation District of Greater Chicago

Chicago, Illinois

February, 2009

Table of Contents

Summary and Conclusions

A seven-year macroinvertebrate database was developed by the Metropolitan Water Reclamation District of Greater Chicago (District) and used herein to characterize the benthic community within the Chicago Area Waterway System (CAWS). This technical memorandum looked at the macroinvertebrate data combined for the entire CAWS, and separately by AWQM station and by reach. Regardless of whether the data were assessed by the CAWS, by station, or by reach, the results are similar; the macroinvertebrate community is dominated by a few opportunistic Diptera and non-insect taxa.

Nearly half of the taxa collected in the CAWS are from the order Diptera, and almost all are in the family Chironomidae. By abundance, oligochaetes (Phylum Annelida) dominate the benthic community, comprising over 74 percent of all macroinvertebrates collected from the CAWS over the seven-year period. Two species of non-native bivalve, the zebra mussel, *Dreissena polymorpha*, and the closely related Quagga mussel, *Dreissena rostriformis bugensis* comprise 15 percent of the samples. These mussels were collected in very high densities in the Calumet area.

Taxa representing the classic pollution-intolerant organisms, the Ephemeroptera, Plecoptera, and Tricoptera (EPT), are exceedingly scarce in the CAWS. Plecopterans are not present at all, and ephemeropterans and tricopterans are found in very low densities with only a few taxa. At most AWQM stations two or fewer EPT taxa were collected, with EPT densities less than one percent.

An analysis of the differences between sampling methods, i.e. grab samples (ponar) and artificial substrate samples (hester-dendy), show that richness measures (total richness, EPT richness, and diptera richness) are higher in the hester-dendy samples. In contrast, EPT taxa were nearly absent from the ponar collections with EPT richness values of zero for most ponar samples. Clearly, the two sampling methods collected different organisms and in different quantities. The ponar grab samples are heavily dominated by oligochaetes, comprising nearly 100 percent of the samples at many stations (and reaches). While the hester-dendy samples also have high numbers of oligochaetes they comprise far less of the sample than in the ponar samples. At several AWQM stations in the Calumet area the hester-dendy samples had high number of zebra and quagga mussels and lower taxa richness. It is likely that these mussels attached themselves to the hester-dendy artificial substrate, covering the samplers in such high numbers that very few other macroinvertebrates could colonize the sampling apparatus.

We also examined the effect of the District's water reclamation plants (WRP) on macronvertebrate communities. We tested the equality of medians for 23 metrics upstream and downstream of the three major treatment plants discharging to the CAWS. We concluded that, for most metrics, there was no difference between the median macroinvertebrate communities upstream and downstream of the three wastewater treatment plants.

Background

Under contract to LimnoTech, Inc., Baetis Environmental Services, Inc. (Baetis) has been retained to analyze macroinvertebrate data collected from the Chicago Area Waterway System (CAWS) between 2001 and 2007. The analysis supports the CAWS Habitat Evaluation and Improvement Study sponsored by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). This technical memorandum is an interim deliverable, providing:

- A general description of the macroinvertebrate populations and communities of the CAWS,
- An analysis of any differences that exist in the macroinvertebrate community between sampling stations and reaches, and
- An analysis of any differences that exist between the grab samples (ponar) and artificial substrate samples (hester-dendy).

Methodology

Macroinvertebrates were collected annually each summer from the CAWS from 2001-2007 by MWRDGC, with enumeration and identification by EA Engineering, Science, and Technology, Inc (EA) of Deerfield, IL. For purposes of study, the CAWS has been divided into twenty reaches. Of these twenty, macroinvertebrate data were collected from seventeen reaches (macroinvertebrate data were not collected from reaches 5, 16, and 20). Twenty-three sampling stations are located throughout the seventeen CAWS reaches. Figure 1 shows the locations of the sampling stations and reaches. The District uses both hester-dendy samplers (multi-plate apparati) and ponar dredge samplers at each AWQM station. Most macroinvertebrates were identified to genus; where possible species-level identifications were completed. A detailed description of the methodology is provided by EA in their 2006 report (EA 2006). LimnoTech, Inc. compiled EA's datasets into one database for this project. Descriptive and inferential statistics were derived for the 2001-2007 macroinvertebrate database using SAS software (Vers. 9.1, SAS Institute Inc. Cary, N.C.)

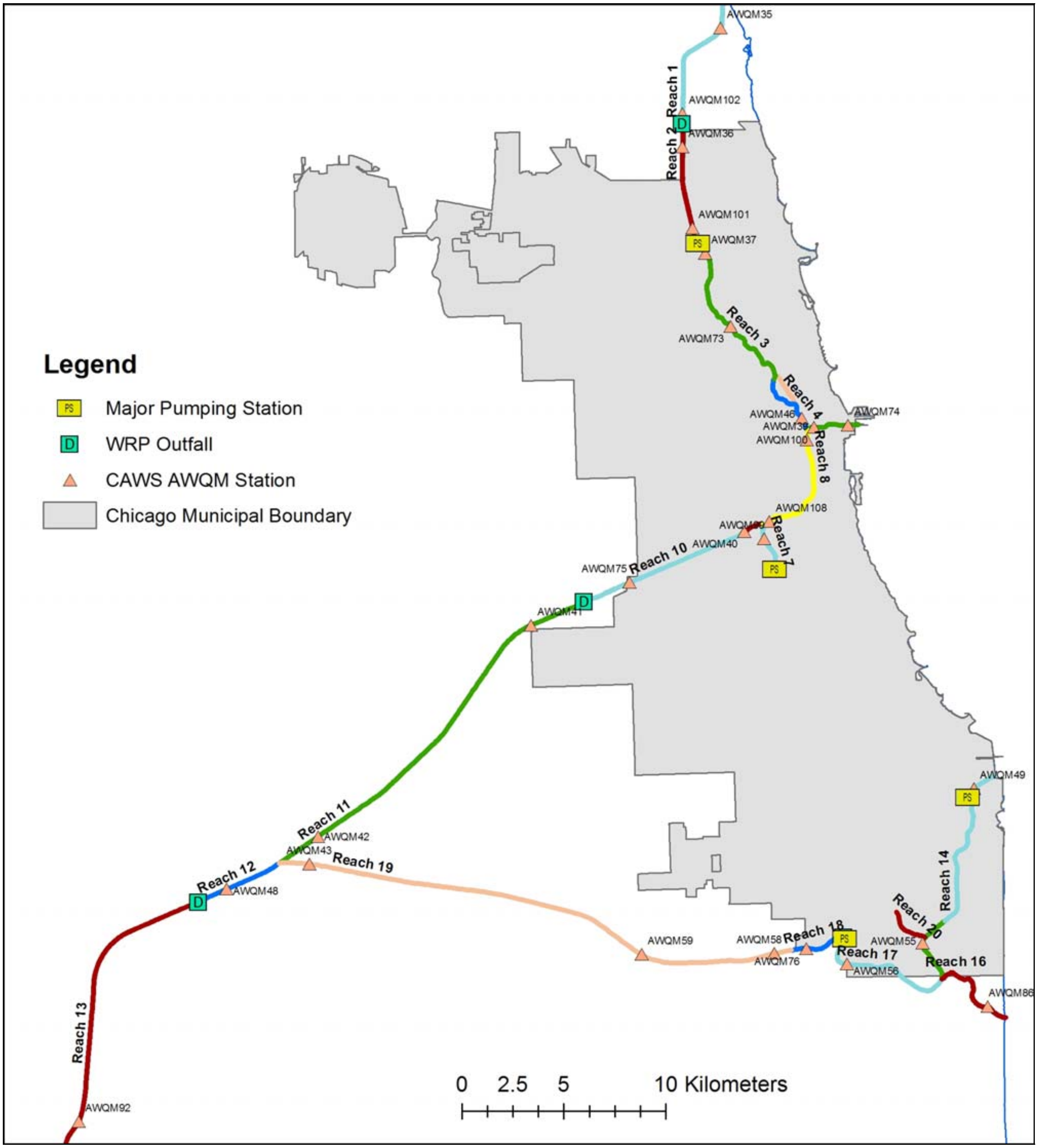

Figure 1. AWQM Station and Reach Designations

Macroinvertebrate Community Composition in the CAWS

General

Over eight million macroinvertebrates were collected and identified between 2001 and 2007. They represented 130 macroinvertebrate taxa, though nearly all the diversity can be attributed to the order Dipera (true flies) and to non-insect taxa such as Oligochaeta, flatworms, leeches, isopods, amphipods, snails, and bivalves (Table 1). Nearly half of the taxa (63) were from the order Diptera, almost all within the family Chironomidae, a family of non-biting flies that can often comprise at least fifty percent of the species diversity in a stream (Coffman et al. 1996). Forty-four non-insect taxa were collected from the CAWS. Outside of the family Chironomidae, taxa richness of the insect community within the CAWS was low. The pollution-sensitive orders Ephemeroptera (mayflies), Tricoptera (caddisflies), and Plecoptera (stoneflies) (EPT) were poorly represented; only fourteen taxa within these orders were collected.

The macroinvertebrate community of the CAWS is dominated by a few pollution-tolerant taxa. Oligochaetes, a class of pollution-tolerant aquatic worms found in soft mud bottoms, comprised nearly 73 percent of all macroinvertebrates collected from the CAWS (Table 2). Two species of non-native bivalve, the zebra mussel, *Dreissena polymorpha*, and the closely related Quagga mussel, *Dreissena rostriformis bugensis* comprised 15 percent of the samples. These invasive species were introduced into the Great Lakes region in ballast water from oceangoing vessels and have had far-reaching and deleterious impacts (Smith 2001, USGS 2008, USDA 2008). True flies (Order Diptera) are the third most abundant taxon, at nearly 6 percent of the collections. Within this order, the family Chironomidae, a family often associated with environmental perturbation, accounted for nearly all the diptera present. In comparison, the densities of pollution-sensitive mayflies, caddisflies, and stoneflies that were collected were very low, comprising only 0.001 percent of the samples. These taxa are often the first to decline in a stressed system.

A shift towards dominance by a few taxa indicates environmental stress. In healthy, natural aquatic systems the macroinvertebrate community is not dominated by a few taxa but, instead, has a more balanced distribution. The percent contribution of such organisms as Oligochaeta and Diptera are expected to increase in response to stream perturbation. These dominant taxa collected from the CAWS are opportunistic taxa that can exist in stressed or man-made environments and are often indicators of poor water quality, poor sediment quality, and/or poor habitat quality.

Assessment By Sampling Station

A description of the macroinvertebrate community collected from each sampling station is provided below. In general, while there are some notable differences between stations, the data show that all stations support a macroinvertebrate community dominated by a few opportunistic taxa in the Diptera and non-insect groups. Figure 1 shows the AWQM stations that the District samples in the CAWS.

Table 1 provides counts of total taxa collected from each station. The highest total richness values were found at AWQM 92 (58 taxa) and AWQM 76 (54 taxa). These stations had more samples taken (28) than many other stations; thus the higher richness values may be a result of increased sampling effort rather than a larger ‘pool’ of macroinvertebrates. Lowest total richness was found at AWQM 99 (14 taxa) and at AWQM 40 (19 taxa), two of the least sampled stations.

EPT richness was low for all stations. In general, two or fewer EPT taxa were collected from each station, although there were some exceptions. AWQM 92 and AWQM 75 had the highest EPT richness values with 7 taxa (AWQM 92) and 6 taxa (AWQM 75). Again, AWQM 92 was one of the most sampled stations; AWQM 75 was also sampled more than many stations. Even considering the number of samples taken at these stations, EPT richness values were low. AWQM stations 46, 99, and 101 had EPT richness values of zero. AWQM 46 was also one of the most sampled stations so an EPT richness value of zero certainly indicates poor aquatic conditions at this site.

Table 2 provides a comparison by station of the macroinvertebrate community composition and functional feeding groups. By abundance, oligochaetes dominate the macroinvertebrate community at most stations. Oligochaetes were found in the highest densities, comprising over half the macroinvertebrates in samples from all but three stations. In fifteen of the 23 stations, oligochaetes comprised over 70 percent or more of the samples. There were only three stations (AWQM 49, 55, and 56) where oligochaetes represented less than half the macroinvertebrates within each sample. Samples from these three stations contained large numbers of zebra mussels and quagga mussels, particularly AWQM 55 (94 percent of the sample) and AWQM 56 (50 percent of the sample).

Table 1

TAXA RICHNESS BY SAMPLING STATION IN THE CHICAGO AREA WATERWAY SYSTEM

		AWQM Sampling Station																						
	CAWS	**35**	**36**	**37**	**39**	**40**	**41**	**43**	**46**	**49**	**55**	**56**	**58**	**59**	**73**	**74**	**75**	**76**	**92**	**99**	**100**	**101**	**102**	**108**
No. of Samples		8	28	8	8	8	28	8	28	8	26	8	8	28	8	8	27	28	28	8	8	8	8	8
Total Richness	130	43	45	24	30	19	41	39	39	49	46	30	36	48	28	36	40	54	58	14	32	22	31	28
EPT Richness	14	2	4	2	1	1	1	3	0	4	3	2	1	2	2	2	6	3	7	0	1	0	2	2
Diptera Richness	63	26	24	14	14	7	19	19	17	30	27	20	16	25	14	23	15	23	25	7	20	11	20	10
Non-insect Richness*	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

.*Calculated for the CAWS.

Table 2

MACROINVERTEBRATE COMMUNITY COMPOSITION AND TROPHIC STRUCTURE METRICS BY SAMPLING STATION, IN THE CHICAGO AREA WATERWAY SYSTEM

		AWQM Sampling Station																						
	CAWS	**35**	**36**	**37**	**39**	**40**	**41**	**43**	**46**	**49**	**55**	**56**	**58**	**59**	**73**	**74**	**75**	**76**	**92**	**99**	**100**	**101**	**102**	**108**
% Diptera	5.9	9.2	7.8	1.6	16.9	4.0	4.7	19.5	4.5	8.1	0.5	11.1	4.2	21.3	3.2	2.5	8.3	9.9	3.5	30.0	8.7	6.8	4.4	16.5
% Chironomid	5.9	9.2	7.8	1.6	16.9	4.0	4.7	19.5	4.5	8.1	0.5	11.1	4.2	21.3	3.2	2.5	8.3	9.9	3.5	30.0	8.7	6.8	4.4	16.5
% Oligochaeta	73	89.4	86.2	95.3	58.0	92.3	87.7	71.9	90.9	15.7	2.9	27.3	93.3	59.9	95.1	72.9	82.5	55.8	90.4	68.4	88.1	81.0	95.1	64.8
% Dreissena sp.	15	0.08	0.01	0	11.7	0	0.38	0.2	0.005	23.6	94.1	50.0	0.9	11.3	0	19.8	0	20.8	0.02	0	0.24	0.04	0	0.45
% EPT	0.001	0.01	0.01	0.003	0.01	0.55	0.12	2.12	0	0.13	0.08	2.24	0.01	0.18	0.002	0.07	0.04	0.27	0.07	0	0.02	0	0.01	1.6
% Shredders	-	0.9	3.3	0.1	0.61	0.21	0.1	7.4	0.2	3.7	0.12	2.7	0.22	1.5	0.29	1.2	0.03	1.36	0.05	0.13	3.0	0.15	0.1	0.45
% Scrapers	-	0.15	0.06	0.02	2.6	0.01	0.09	0.08	0.03	0.16	0.08	0.01	0.33	0.89	0.02	0.17	0.12	0.98	0.84	1.2	0.65	0.1	0.03	0.5
% Collector-filterers	-	0.52	0.01	0.01	11.8	0.21	0.43	0.44	0.06	23.8	94.2	50.1	0.98	11.8	0.003	19.8	0.33	21.3	0.44	0.11	0.31	0.06	0.01	2.5
% Collector-gatherers	-	96.4	93.5	96.4	74.2	96.1	92.2	77.3	95.1	18.9	3.3	36.3	96.4	76.8	97.9	73.9	90.3	62.7	92.8	97.9	95.9	87.6	99.0	79.9
% Predators	-	1.5	5.5	3.3	5.4	3.1	6.4	14.4	4.3	52.6	0.5	12.3	1.7	6.8	1.9	0.57	8.7	10.0	3.9	0.82	0.94	11.5	0.75	14.7

The invasive zebra mussel and the quagga mussels appear to have a patchy distribution within the CAWS with the highest numbers found in AWQM 55 (94 percent) followed by AWQM stations 56, 49 and 76 (see Table 2 - % Dreissena sp.). These stations are in the Calumet area, an area that supports heavier barge traffic than the other reaches on the CAWS. It is probable that barge and boat traffic in this area contributed to the spread of zebra and quagga mussels in this area, although we cannot dismiss the Lake Michigan diversion flows through the Calumet River. Far fewer numbers of these species are found at other AWQM stations in the CAWS, and the mussels are absent from many other reaches.

The average percent EPT (PER_EPT) was very low for all stations with the highest percentages just at 2 percent (AWQM 43 and AWQM 56) (Table 2). AWQM 108 had the third highest PER_EPT at just over 1.5 percent. The remaining stations had average EPT densities of less than 1 percent per sample.

In non-wadeable natural rivers the typical macroinvertebrate assemblage is dominated by collector functional feeding groups (USEPA 2006). In the CAWS, nearly all stations are dominated by the collector functional feeding group. At many stations collector-gatherers, heavily represented by oligochaetes, comprise 90+ percent of the community. These taxa feed by collecting organic particles from the debris and sediments on the bed of a stream. High numbers of collector filterers are found at only a few stations, AWQM 55 (94 percent), AWQM 56 (50 percent) and AWQM 49 (24 percent). Collector-filterers feed by collecting organic particles from the water column using a variety of filters. Zebra mussels and quagga mussels are present in AWQM stations 55 and 56 in very high numbers; these collector-filterer taxa also make up a large part of the macroinvertebrate community collected in AWQM 49 and AWQM 76 although in smaller numbers. From the data, it is evident that the relative abundance of the different functional feeding groups is closely correlated with the relative abundance of oligochaetes, zebra mussels, and quagga mussels.

Shredders appear in the samples in far fewer numbers, comprising less than one percent of the macroinvertebrate population at many stations. AWQM 43, at 7.4 percent, has the highest proportion of shredders. Shredders feed on leaf litter and other organic material from the riparian zone in smaller, natural, headwater streams. They convert this leaf litter, or coarse particulate organic matter (CPOM) to fine particular organic matter (FPOM) which is consumed by the collector functional feeding group in downstream reaches. The CAWS, which is a larger non-wadeable, manmade waterway, supports a macroinvertebrate community that is strongly comprised of the collector functional feeding group. It appears from the data that the influence of the riparian zone and CPOM input is reduced throughout the waterway and limits this feeding group.

Scrapers are rarer than shredders in the CAWS with the highest percentages collected from AWQM 39 (2.6 percent) and AWQM 99 (1 percent). All other stations had scraper percentages less than one percent.

Assessment By Reach

For planning purposes, the macroinvertebrate metrics were also calculated by reach; the results are shown in Table 3. Designated reaches are shown in Figure 1. The trends observed by reach correspond to the trends observed at each sampling station, i.e. within each reach the macroinvertebrate community is dominated by a few taxa in the Diptera and non-insect groups.

Consistent with the station data, the highest total richness values are found in reaches 13, 19, and 18 with 58 taxa found in reaches 13 and 19, and 54 taxa collected in reach 18. Reaches 13 and 18 contain stations AWQM 92 and 76 which had the highest taxa richness out of all samples; reach 19 contains AWQM 43 and 59, which also had high taxa richness scores. Lowest total richness was found in reaches 12 and 7, with 6 and 14 taxa, respectively. These are also two of the least sampled reaches. Reach 7 is the heavily contaminated Bubbly Creek waterway so it is not surprising that the richness values are low. Reach 12 was sampled only once during the 2001-2007 period.

With the exception of reaches 10 and 13, four or fewer EPT taxa were collected from each reach. Six EPT taxa were collected from reach 10; seven EPT taxa were collected from reach 13. The stations with the highest EPT richness, AWQM 92 and AWQM 75, are the only stations located within these reaches.

In nine of the 17 reaches, oligochaetes comprised 80 percent or more of the samples. There were only four reaches (reaches 12, 14, 15, and 17) where oligochaetes represented less than half the macroinvertebrates within each sample. Reaches 14, 15, and 17 are in the Calumet area where other non-insect invertebrates, primarily invasive zebra and quagga mussels, have replaced oligochaetes as the most abundant organism.

The average percent dominance is also provided in Table 3. As expected, the average percent dominance for each reach is high. Again, the assemblage within each reach is dominated by a few taxa which have resulted in lowered diversity. With the exception of reach 12 (which was only sampled once), each reach has average percent dominance values over 65 percent; with many reaches with average percent dominance values over 80 percent. Based upon the single sample, reach 12 does not appear to be dominated by oligochaetes nor are there one or two taxa exceedingly dominant in the samples. However, a close look at the macroinvertebrates collected from reach 12 during the single sampling event indicate that a sample dominated by oligochaetes, flatworms, chironomids, leeches, and the exotic Asiatic clam *Corbidula* and zebra mussel. Reaches 14, 15, and 17 have high average percent dominance values, however, the samples collected from these reaches are not dominated by oligochaetes; instead, these communities are dominated by hydra and quagga mussels (reach 14) and quagga mussels and zebra mussels (reaches 15 and 17).

The percent EPT is very low for all reaches, the maximum being 2% (in reach 17). While reach 17 has low EPT richness with only 2 taxa, the numbers of individuals appear to be higher than in other reaches. The remaining reaches have average EPT densities of less than 1 percent per sample.

High numbers of collector filterers, present as zebra mussels, quagga mussels, and the Asiatic clam, *Corbicula fluminea* (reach 12 only), are found in only a few reaches. Reach 12 had 39 percent collector filterers, reach 14 had 24 percent, reach 15 had 94 percent, and reach 17 had 50 percent. AWQM 49, 55, and 56 are the only stations within reaches 14, 15, and 17 so the results are the same for both. Shredders appear throughout in far fewer numbers, comprising less than one percent in many reaches. Reach 14, at 3.7 percent, has the highest number of shredders.

Table 3

MACROINVERTEBRATE COMMUNITY COMPOSITION AND TROPHIC STRUCTURE METRICS BY REACH

	CAWS	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**17**	**18**	**19**
Total Richness	130	50	47	33	39	45	14	38	19	40	44	6	58	49	46	30	54	58
EPT Richness	14	3	4	2	0	2	0	3	1	6	2	0	7	4	3	2	3	4
Diptera Richness	63	30	24	18	17	29	7	15	7	15	21	1	25	30	27	20	23	28
Non-insect Richness	44	16	18	13	22	14	7	19	10	19	19	5	24	15	16	8	25	24
% Diptera	5.9	5.8	7.7	2.5	4.5	5	30	16.7	4	8.3	4.7	8.7	3.5	8.1	0.5	11.1	9.9	11.1
%Chir	5.9	5.8	7.7	2.5	4.5	5	30	16.7	4	8.3	4.7	8.7	3.5	8.1	0.5	11.1	9.9	11.1
% Olig	73	93.3	85.7	95.2	90.9	79	68.4	60.6	92.3	82.5	87.6	13.1	90.4	15.7	2.9	27.3	55.8	80.5
% Dreis.	15	0.02	0.01	0	0.005	12	0	7	0	0	0.4	35	0.02	24	94	50	21	4
% Dom*	-	76	74.7	81.8	85.6	78.4	86.8	75.0	85.1	85.7	82.2	34.8	69.7	71.2	86.1	74.3	71.0	65.9
% EPT	0.001	0.01	0.01	0.003	0	0.05	0	0.62	0.55	0.04	0.18	0	0.07	0.13	0.08	2.2	0.27	0.27
% Shred	-	0.34	3.01	0.21	0.2	1.9	0.13	0.55	0.21	0.03	0.1	0	0.05	3.7	0.1	2.7	1.4	1.3
% Scrapers	-	0.07	0.06	0.02	0.03	0.37	1.2	1.8	0.01	0.12	0.1	0	0.84	0.16	0.08	0.01	1.0	0.49
% Cltr-fltrs	-	0.16	0.02	0.007	0.06	11.9	0.11	8.2	0.21	0.33	0.43	39.1	043.	23.8	94.2	50.1	21.3	4.42
% Cltr-gthrs	-	98.2	93.0	97.3	95.1	82.8	97.8	76.4	96.1	90.3	92.1	13.0	92.8	18.9	3.25	36.3	62.7	88.3
% Predtrs	-	1.0	6.1	2.5	4.32	0.72	0.82	9.04	3.12	8.71	6.44	47.8	3.9	52.6	0.5	12.3	10.0	4.52

*This value represents the average percent dominance per sample.

Comparison Between Sampling Protocols

We investigated differences, if any, between the grab samples (ponar) and artificial substrate samples (hester-dendy). Clearly, the two sampling methods collect different organisms in different quantities. Table 4 compares the results of the two sampling methods for the entire CAWS; Tables 5 through 7 compare the results of the two sampling methods by sampling station. Comparisons by reach are presented in Tables 7 and 8.

Greater numbers of macroinvertebrates were collected using a ponar sampler than the hester-dendy apparatus (Table 4); importantly however, taxa richness was much higher in the hester-dendy samples. Richness measures were, in fact, much higher in the hester-dendy samples for every richness category assessed. Thus, while higher numbers were collected with the ponar in the CAWS, the ponar samples collected fewer taxa and had overall lower diversity.

Community composition measures for the CAWS show that the hester-dendy samples had higher percentages of Diptera and EPT individuals. Hester-dendy samples also had higher numbers of the invasive zebra mussel and quagga mussel (Genus Dreissena). Ponar grab samples, in comparison, had very high numbers of oligochaetes; comprising 97 percent of the ponar samples for the CAWS. Oligochaetes make up only 65 percent of the hester-dendy samples for the CAWS (Table 4).

Because oligochaetes, which fall within the collector-gatherer functional feeding group, make up the vast majority of the macroinvertebrate collections in the ponar grab samples, it is not surprising that this sampling technique has a much higher percentage of collector-gatherers. In contrast, the hester-dendy samples have a much lower percentage of collector-gatherers and a higher percentage of the shredder, scraper, collector-filterer, and predator functional feeding groups. This is likely the result of the higher macroinvertebrate diversity found in the hester-dendy samples.

Station-wise and reach-wise comparisons show similar patterns (Tables 5-7 and Tables 8-9). With only two exceptions (AWQM 101, one of two stations in reach 2, and AWQM 55 the only station in reach 15) total richness and EPT richness values are higher in the hester-dendy samples for each station and reach. The ponar grab method did not collect EPT taxa from most stations, while the hester-dendy method collected EPT taxa from all stations with the exception of three. With few exceptions, Diptera richness is also higher in the hester-dendy samples.

Table 4

COMPARISON OF PONAR AND HESTER-DENDY SAMPLING METHODS

	Ponar	**Hester-Dendy**
Total # Samples Collected	176	171
Total # of Individuals	5,091,260	3,192,962
Richness Measures		
Total Richness	81	111
EPT Richness	5	13
Ephemeroptera Richness	2	5
Tricoptera Richness	3	8
Diptera Richness	43	53
Community Composition and Functional Feeding Group		
% Diptera	1.9	12
%Chironomidae	1.9	12
% Oligochaeta	97	65
% Dreissena	0.4	39
% EPT	0.005	0.3
% Shredders	0.3	2.5
% Scrapers	0.03	0.6
% Collector-filterers	0.6	38.7
% Collector-gatherers	97.5	47.3
% Predators	1.7	10

As discussed above, throughout the CAWS higher numbers of individuals were collected using the ponar sampling method (Table 4). That said, when looking at a station comparison and a reach by reach comparison, one can see that in approximately half the stations and reaches the hester-dendy samples have higher numbers of macroinvertebrates than the ponar samples. It is interesting to note that in AWQM 55 (the only station in reach 15) macroinvertebrates were collected in vastly greater numbers using the hester-dendy (1,079,540 individuals) than the ponar (39,746 individuals) yet the hester-dendy samples at this site have lower richness values for several metrics in comparison to the ponar samples. The high numbers of macroinvertebrates coupled with low diversity in reach 15 can be explained by the very high numbers of the invasive zebra mussels and quagga mussels that dominate the hester-dendy samples. It is likely that these mussels attached themselves to the hester-dendy artificial substrate in reach 15 (and to a lesser extent in reaches 14, 17, and 18) covering the samplers in such high numbers that very few other macroinvertbrates could colonize the sampling apparatus.

As in the overall CAWS, the ponar grab samples are heavily dominated by oligochaetes, comprising nearly 100 percent of the samples at many stations (and reaches). While the hester-dendy samples also have high numbers of oligochaetes they comprise far less of the sample than in the ponar samples. In conjunction with the high oligochaete percentages, collector-gatherers are the dominant functional feeding group in the ponar samples collected from each station (and reach).

Table 5

COMPARISON OF METRICS FOR PONAR AND HESTER-DENDY SAMPLING METHODS, AWQM STATIONS 35-43

	AWQM 35		**AWQM 36**		**AWQM 37**		**AWQM 39**		**AWQM 40**		**AWQM 41**		**AWQM 43**	
	PN	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**
Total # Samples	4	4	14	14	4	4	4	4	4	4	14	14	4	4
Total # of Individuals (m^2)	153,896	9,559	1,441,758	487,492	275,037	46,499	10,794	25,059	54,743	16,164	429,809	362,938	53,250	18,059
Total Richness	19	37	27	39	11	21	11	27	7	18	25	33	10	35
EPT Richness	0	2	0	4	0	2	0	1	0	1	1	1	0	3
Diptera Richness	12	21	16	19	8	11	5	13	4	6	11	13	6	16
% Diptera	6.7	48.7	1.6	26.2	1.2	3.7	1.1	23.7	0.4	16.0	0.7	9.4	10.0	47.4
%Chironomidae	6.7	48.7	1.6	26.2	1.2	3.7	1.1	23.7	0.4	16.0	0.7	9.4	10.0	47.4
% Oligochaeta	92.6	37.6	97.4	53.2	98.6	75.8	59.2	57.5	99.3	68.5	96.2	77.6	89.7	19.6
% Dreissena sp.	6.7	0.11	1.6	0.03	1.2	0	1.1	0.29	0.39	0	0.74	0.82	10.0	0.77
% EPT	0	0.11	0	0.05	0	0.02	0	0.01	0	2.4	0.0003	0.26	0	8.4
% Shredders	0.88	1.2	0.17	12.6	0.08	0.2	0.13	0.82	0.26	0.04	0.08	0.13	0	29.1
% Scrapers	0.04	2.0	0.005	0.22	0	0.16	0	3.7	0	0.04	0.11	0.07	0	0.30
% Collector-filterers	0.54	0.11	0	0.05	0.01	0.02	38.6	0.29	0.26	0.02	0.01	0.92	0.19	1.2
% Collector-gatherers	97.3	81.9	98.6	78.6	99.3	79.3	59.8	80.4	99.6	84.3	96.8	86.7	89.8	40.4
% Predators	1.1	7.4	2.0	15.8	0.76	18.4	1.3	7.2	0.16	13.1	2.8	10.6	9.9	27.6

Table 6

COMPARISON OF METRICS FOR PONAR AND HESTER-DENDY SAMPLING METHODS, AWQM STATIONS 46-73

	AWQM 46		AWQM 49		AWQM 55		AWQM 56		AWQM 58		AWQM 59		AWQM 73	
	PN	HD	PN	HD	PN	HD	PN	HD	PN	HD	PN	HD	PN	HD
Total # Samples	14	14	4	4	14	12	4	4	4	4	14	14	4	4
Total # of Individuals (m2)	213,764	186,046	11,942	36,118	39,746	1,079,540	12,301	47,485	407,934	31,026	118,501	124,202	404,117	42,874
Total Richness	21	32	29	36	36	27	13	25	6	33	25	43	10	22
EPT Richness	0	0	0	4	2	1	0	2	0	1	0	2	0	2
Diptera Richness	10	15	24	18	20	15	10	15	2	15	13	21	5	9
% Diptera	0.4	9.3	27.2	1.9	4.9	0.34	11.2	11.1	0.82	48.0	6.1	35.8	0.51	28.6
%Chironomidae	0.4	9.3	27.2	1.9	4.9	0.34	11.2	11.1	0.82	48.0	6.1	35.8	0.51	28.6
% Oligochaeta	99.4	81.0	55.5	2.6	63.4	0.71	88.6	11.4	99.0	18.4	92.1	29.1	99.4	54.0
% Dreissena sp.	0.40	0.002	27.2	25.8	4.9	96.5	11.2	62.9	0	12.7	0.59	21.4	0	0
% EPT	0	0	0	0.17	0.14	0.07	0	2.8	0	0.13	0	0.36	0	0.03
% Shredders	0.03	0.39	12.1	0.97	1.9	0.04	1.3	3.1	0	3.2	0.07	2.9	0	3.0
% Scrapers	0	0.07	0	0.22	0.18	0.08	0	0.02	0	4.7	0.01	1.7	0	0.16
% Collector-filterers	0.09	0.01	17.1	26.0	30.0	96.5	0.23	63.0	0.08	12.8	1.48	21.7	0	0.03
% Collector-gatherers	99.6	90.0	66.1	3.2	64.6	0.99	91.1	22.1	99.0	62.7	92.7	61.6	99.7	80.8
% Predators	0.38	8.9	7.7	67.5	2.2	0.44	7.4	13.6	0.82	12.9	5.38	8.1	0.49	15.4

Table 7

COMPARISON OF METRICS FOR PONAR AND HESTER-DENDY SAMPLING METHODS, STATIONS 74-108

	AWQM 74		**AWQM 75**		**AWQM 76**		**AWQM 92**		**AWQM 99**		**AWQM 100**		**AWQM 101**		**AWQM 102**		**AWQM 108**	
	PN	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**
Total # Samples	4	4	14	13	14	14	14	14	4	4	4	4	4	4	4	4	4	4
Total # of Individuals (m2)	19,148	7,711	41,841	158,637	317,984	231,845	612,583	95,939	7,005	25,763	7,018	11,260	124,013	77,772	318,945	53,659	10,493	12,451
Total Richness	8	36	14	36	34	47	17	52	3	13	5	29	17	16	19	22	10	25
EPT Richness	0	2	1	5	0	3	1	7	0	0	0	1	0	0	0	2	0	2
Diptera Richness	5	23	7	13	17	19	9	20	1	6	2	19	10	7	11	14	5	9
% Diptera	0.98	6.4	0.82	10.2	5.2	16.4	1.4	16.9	0.82	37.9	0.41	13.8	1.3	15.5	0.46	27.6	3.3	27.6
%Chironomidae	0.98	6.4	0.82	10.2	5.2	16.4	1.4	16.9	0.82	37.9	0.41	13.8	1.3	15.5	0.46	27.6	3.3	27.6
% Oligochaeta	97.2	12.7	97.8	78.4	90.6	8.1	97.7	43.6	99.0	60.1	99.2	81.1	97.9	54.2	99.4	69.6	92.2	41.7
% Dreissena sp.	1.9	64.2	0	0	0.28	49.0	0	0.14	0	0	0.21	0.25	0.06	0	0	0	0.96	0.03
% EPT	0	0.23	0.03	0.04	0	0.64	0.02	0.35	0	0	0	0.03	0	0	0	0.07	$0	2.9
% Shredders	0.45	3.1	0.07	0.02	1.81	0.75	0	0.37	0	0.17	0.21	4.7	0.03	0.32	0.01	0.64	0.14	0.72
% Scrapers	0	0.61	0.03	0.14	0.07	2.2	0.07	5.8	0	1.5	0	1.1	0	0.25	0	0.2	0	0.98
% Collector-filterers	1.87	64.3	1.0	0.14	1.1	49.1	0.32	1.2	0	0.14	0.41	0.25	0.09	0	0.009	0	4.5	0.86
% Collector-gatherers	97.5	15.4	98.0	88.3	91.3	23.4	98.0	59.2	99.0	97.6	99.2	93.8	99.1	69.3	99.5	96.3	93.0	68.8
% Predators	0.23	1.4	0.76	10.8	2.9	19.9	1.2	21.1	1.0	0.77	0	1.5	1.0	28.3	0.43	2.6	2.3	25.1

Table 8

COMPARISON OF METRICS FOR PONAR AND HESTER-DENDY SAMPLING METHODS, REACHES 1-10,

	Reach 1		**Reach 2**		**Reach 3**		**Reach 4**		**Reach 6**		**Reach 7**		**Reach 8**		**Reach 9**		**Reach 10**	
	PN	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**
Total # Samples Collected	8	8	18	18	8	8	14	14	8	8	4	4	8	8	4	4	14	13
Total # of Individuals (m^2)	472,840	63,218	1,565,771	565,264	679,154	89,373	213,764	186,046	26,166	18,971	7,005	25,763	21,286	37,510	54,743	16,165	41,841	158,637
Total Richness	25	42	30	41	16	29	21	32	11	44	3	13	15	34	7	18	14	36
EPT Richness	0	3	0	4	0	2	0	0	0	2	0	0	0	3	0	1	1	5
Ephemeroptera Richness	0	2	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	2
Tricoptera Richness	0	1	0	3	0	1	0	0	0	2	0	0	0	2	0	1	0	3
Diptera Richness	15	25	17	20	10	14	10	15	7	28	1	6	6	14	4	6	7	13
% Diptera	2.5	31	1.5	25	0.8	16	0.4	9	0.8	11	0.8	38	2.2	25	0.4	16	0.8	10
%Chironomidae	2.5	31	1.5	25	0.8	16	0.4	9	0.8	11	0.8	38	2.2	25	0.4	16	0.8	10
% Oligochaeta	97	65	97	53	99	65	99	81	98	53	99	60	75	52	99	68	98	78
% Dreissena sp.	0.02	0.02	0.005	0.03	0	0	0.007	0	1.4	26	0	0	20	0.2	0	0	0	0
% EPT	0	0.07	0	0.04	0	0.02	0	0	0	0.11	0	0	0	0.97	0	2.4	0	0.04
% Shredders	0.29	0.7	0.16	10.9	0.03	1.6	0.03	0.4	0.38	4.1	0	0.17	0.14	0.79	0.26	0.04	0.07	0.03
% Scrapers	0.01	0.5	0.005	0.23	0	0.16	0	0.07	0	0.87	0	1.53	0	2.8	0	0.05	0.03	0.14
% Collector-filterers	0.18	0.02	0.01	0.05	0	0.03	0.09	0.01	1.48	26.3	0	0.14	21.78	0.48	0.26	0.02	1.03	0.14
% Collector-gatherers	98.8	94.1	98.6	77.3	99.6	80	99.6	90	97.9	61.9	99	97.6	76.2	76.5	99.6	84.3	98	88
% Predators	0.65	3.4	1.93	17.5	0.6	16.9	0.38	8.9	0.17	1.5	1.02	0.77	1.82	13.1	0.16	13.1	0.76	10.8

PN = Ponar Grab Sample

HD = Hester-dendy Artificial Substrate Sample

Table 9

COMPARISON OF METRICS FOR PONAR AND HESTER-DENDY SAMPLING METHODS, REACHES 11-20

	Reach 11		Reach 12		Reach 13		Reach 14		Reach 15		Reach 17		Reach 18		Reach 19	
	PN	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**	**PN**	**HD**
Total # Samples Collected	17	16	1	0	14	14	4	4	14	12	4	4	14	14	22	22
Total # of Individuals (m^2)	434,115	367,801	330	-	612,583	95,940	11,942	36,118	39,746	1,079,540	12,301	47,485	317,984	231,845	579,687	173,287
Total Richness	26	35	6	-	17	52	29	36	36	27	13	25	34	47	28	52
EPT Richness	1	2	0	-	1	7	0	4	2	1	0	2	0	3	0	4
Ephemeroptera Richness	0	0	0	-	0	2	0	0	1	0	0	1	0	0	0	2
Tricoptera Richness	1	2	0	-	1	5	0	4	1	1	0	1	0	3	0	2
Diptera Richness	12	14	1	-	9	20	24	18	20	15	10	15	17	19	15	23
% Diptera	0.7	9	8.7	-	1.4	17	27.2	2	4.9	0.34	11.2	11	5.2	16	2.7	39
%Chironomidae	0.7	9	8.7	-	1.4	17	27.2	2	4.9	0.34	11.2	11	5.2	16	2.7	39
% Oligochaeta	96	77	13	-	98	44	56	3	63	1	89	11	91	8	97	26
% Dreissena sp.	0	0.8	35	-	0	0.14	17	26	30	97	0.2	63	0.3	49	0.12	18
% EPT	0.003	0.39	0	-	0.023	0.35	0	0.17	0.145	0.07	0	2.8	0	0.64	0	1.1
% Shredders	0.08	0.13	0	-	0	0.37	12.14	0.97	1.91	0.04	1.28	3.1	1.81	0.75	0.01	5.6
% Scrapers	0.11	0.09	0	-	0.07	5.8	0	0.22	0.18	0.08	0	0.01	0.07	2.2	0.002	2.1
% Collector-filterers	0.01	0.93	39.13	-	0.32	1.2	17.1	26	30.1	96.5	0.23	63	1.05	49	0.38	18
% Collector-gatherers	96.9	86.6	13.1	-	98	59.2	66.1	3.2	64.6	0.99	91.1	22.1	91.3	23.4	96.8	59.6
% Predators	2.7	10.8	47.8	-	1.2	21	7.7	67.5	2.2	0.44	7.3	13.6	2.8	19.9	2.6	11

PN = Ponar Grab Sample

HD = Hester-dendy Artificial Substrate Sample

Comparison of the Benthic Community Upstream and Downstream of WRPs

We examined the effect of sampling method on measuring the effects of District water reclamation plants (WRP) on macronvertebrate metrics. Metrics were taken from Wessel *et al*. (2008). We tested the equality of medians for each metric upstream and downstream of the three major treatment plants discharging to the CAWS. The data are not normally distributed and could not be readily transformed to approximate a normal distribution. Therefore we performed the non-parametric Kruskal-Wallis 'ANOVA' test. We concluded that, for most metrics, there was no difference between the median macroinvertebrate metrics upstream and downstream of the District's three major WRPs (Table 8).

A few metrics do, however, show a statistical difference upstream and downstream of the WRPs. In no case do the results of the Krustal-Wallis test using ponar data agree with the results from the same test using hester-dendy data. This supports our belief that the sampling protocols measure different populations. We therefore present Table 8 with caution, and remind readers that non-parametric methods, while more robust (fewer assumptions), do not have the power of parametric methods. That said, the following conclusions can be made from the Krustal-Wallis testing: % collector-filterers (CF) and T_BFPOM metrics, indicate differences between upstream and downstream benthic communities at the North Side and Stickney WRPs. The T_BFPOM metric measures the ratio of the total number of collector filterers to the total number of collector gatherers. At the Calumet WRP, the median percentage of EPT taxa and the median percentage of Tricoptera taxa from the hester-dendy samples are statistically different upstream and downstream. The percentage of Diptera (and percentage of chironomids) from the ponar samples also show significant differences upstream and downstream of the Calumet WRP.

Table 8

P-VALUES FROM TESTS OF EQUAL MEDIANS IN THE MACROINVERTEBRATE METRICS UPSTREAM AND DOWNSTREAM OF THREE WRPS

Metric	Reach					
	North Side WRP (Reaches 1 & 2)		Stickney WRP (Reaches 10 & 11)		Calumet WRP (Reaches 17 & 18)	
	PN	HD	PN	HD	PN	HD
% Collector-Filterer	0.0094*	0.8413	0.0013*	0.7313	0.0696	0.8734
% Collector-Gatherer	0.8894	0.0106*	0.1103	0.0721	0.9154	0.9154
C_FPOM	0.5931	0.0472*	0.4810	0.0612	0.2120	0.2403
Diptera Richness	0.9776	0.9776	0.4494	0.1605	0.0748	0.1305
EPT_DIP	1.0	0.6864	0.8522	0.1639	1.0	0.9570
EPT Richness	1.0	0.5717	0.8888	0.1522	1.0	0.4085
Ephemeroptera Richness	1.0	0.1464	0.2705	0.2673	1.0	0.0614
FFG_DIV	0.8014	0.8673	0.6959	0.2529	0.1487	0.5538
HAB_STAB	0.1082	0.1882	0.0067*	0.9267	0.0547	0.9154
% Chironomidae	0.7595	0.2433	0.9674	0.3686	0.0250*	0.75
% Diptera	0.7595	0.2433	0.8380	0.3686	0.0250*	0.75
% Dominance	0.6565	0.7389	0.1522	0.0956	0.9154	0.2882
% Ephemeroptera	1.0	0.1332	0.2705	0.2673	1.0	0.0614
% EPT	1.0	0.5184	0.8522	0.0650	1.0	0.0424*
% Oligochaeta	0.6565	0.6171	0.1522	0.1360	0.9154	0.6708
% Tricoptera	1.0	0.8250	0.3642	0.0500*	1.0	0.0424*
% Predators	1.0	0.0015*	1.0	0.1355	0.0534	0.9154
P_R FFG	0.4647	0.1386	0.7964	0.4081	0.3248	1.0
Taxa Richness	0.8451	1.0	0.7600	0.1404	0.3931	0.8721
% Scrapers	0.6863	0.4401	0.9258	0.9808	0.3267	0.004*
% Shredders	0.5931	0.0883	0.4810	0.0575	0.2120	0.2002
T_BFPOM	0.0076*	0.8413	0.0013*	0.7313	0.0696	0.9576
Tricoptera Richness	1.0	0.7565	0.3642	0.1445	1.0	0.8073

*$p \leq 0.05$. Upstream and downstream reaches are statistically different.

References

Coffman, W. P. and L.C. Ferrington. 1996. *In* An Introduction to the Aquatic Insects of North America, Third Edition. R. W. Merrit and K.W. Cummins (*eds.*). Kendall/Hunt Publishing Company, Dubuque, IA.

EA Engineering, Science and Technology, Inc. (EA). 2006. A Study of the Benthic Macroinvertebrate Community in Selected Metropolitan Area Waterways during 2003 and 2004. Metropolitan Water Reclamation District Report #07-47.

Smith, D.G. 2001. Pennak's Freshwater Invertebrates of the United States. Fourth Edition. John Wiley & Sons, Inc. New York.

United States Department of Agriculture (USDA). 2008. National Invasive Species Information Center. http://www.invasivespeciesinfo.gov/aquatics/quagga.shtml. Accessed 1/12/09.

United States Environmental Protection Agency (USEPA). 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. EPA/600/R-06/127. Washington, D.C.

United States Geological Survey (USGS). 2008. Zebra and Quagga Mussel Resource Page. http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/. Accessed 01/12/09.

Wessel, K.J., R.W. Merrit, J.O. Wilhelm, J.D.Allan, K.W. Cummins, and D.G. Uzarski. 2008. Biological evaluation of Michigan's non-wadeable rivers using macroinvertebrates. Aquatic Ecosystem Health & Management 11(3):335-351.