A Macroinvertebrate Study of the Shenango River Westinghouse Superfund Site, Sharon, PA

by

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ABSTRACT

The previous spills and releases of polychlorinated biphenyls (PCB) into the Shenango River caused the Westinghouse Site to become a superfund. With the superfund concluded, our goal was to compare the dredged areas of the Westinghouse Superfund site in the Shenango River to the channel areas which were not remediated. Replicate ponar grab samples were taken in remediated areas, in the non-remediated areas and at an upstream reference site on three days between summer, fall 2007 and spring 2008 seasons. Thirty-five total taxa were collected and were dominated by the chironomid genera. Also Identified were a chironomid *chironomus* mentum deformity incidence, tolerance index value. A multivariate analysis of variance was done on date and site type for abundance, richness and tolerance index. Site type was not significant, meaning there was no statistical significance between reference, non-remediated and remediated sites. Date was found significant as expected by the phenology of macroinvertebrates emergence. The depression of abundance and richness values, chironomid deformity incidence and tolerance index suggest mild stress on the site sampled. This stress could be from one or more sources such as urbanization or the upstream landfill. This study can prove to be a valuable baseline for future studies at the Westinghouse Site or the Shenango River.

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Chapter I Introduction

Shenango River/Westinghouse History

The Shenango River superfund site is located adjacent to the former Westinghouse plant in Sharon, Pennsylvania. This plant occupies approximately 58 acres and reaches approximately 1600 meters in length and up to 800 meters in width (Cummings Riter Consultants Inc. 2004). Most of the plant area is covered by concrete, asphalt and buildings, with the exception of an area in the southwest section of the site.

The Westinghouse property has resided among commercial and industrial areas since the mid-1800s (Cummings Riter Consultants Inc. 2004). This plant is currently part of an industrial zone headed by the Shenango Valley Industrial Development Corporation and Penn Northwest Development Corporation. The 400 meter stretch of the Shenango River that runs along the former Westinghouse plant property is the area of concern, receiving discharge water from two storm sewers from the plant (Figure 1.0). One storm sewer releases storm water from the plant’s north sector and the northern part of the middle sector. The other storm water drain expels water from the southern part of the middle sector and the moat area of the plant (Cummings Riter Consultants Inc. 2004).

In addition to these drains leading contaminants into the Shenango River, there have been releases of chemicals from underground storage tanks (USEPA 2007). At least one leak released over 6,000 gallons of oils and solvents into the environment. These leaks and spills contaminated the Shenango River sediments, ground water and riparian soils with polychlorinated biphenyls (PCBs). This becomes an environmental health concern as well as a human health risk because the Westinghouse Plant is adjacent to the portion of the Shenango River that is upstream of the Aqua America Water Company, which provides drinking water to the surrounding area. Because of these risks, the Westinghouse was placed on the National Priorities List in 1990 (USEPA 2007).

Westinghouse Background

- The Westinghouse plant was acquired in 1922 and produced transformers and related electrical components until its operations ended in 1984.

- During World War II the plant was used by the United States government to develop and produce transformers, transformer core.

- Westinghouse filed for a notification of hazardous waste activity to treat, store or dispose of hazardous waste in 1980.

- In 1983 they switched their status to a hazardous waste generator only.

- In 1985, Pennsylvania Department of Environmental Resources, PADER, ordered Westinghouse to do an investigation to evaluate the soil and ground water impacted from its operations and submit a plan for remediation.

- In 1994 the USEPA wanted to prevent the possible dissemination of light non-aqueous phase liquids (LNAPLs), liquids that are less dense than and does not mix with water, into groundwater from the tank farm area in the middle sector of the Westinghouse plant by issuing a response action plan for removing these liquids.

- From 1996 to 1998, the Westinghouse submitted final reports for remedial impact, ecological risk assessment, and a baseline human health risk assessment.

- Initiation of remediation of contaminated soils (lead and polychlorinated biphenyl) in 2001 and completed in fall of 2003 by Viacom, Winner and AK Steel

After results of soil sampling were finished in 2000, Viacom sent a feasibility study for river sediment. Groundwater was not addressed until 2002 where a report titled Technical Impracticability of Groundwater Restoration Evaluation was sent by Viacom to the USEPA where it was approved.

In 2003, the USEPA made a record of decision (ROD) to implement clean up of river sediments and riparian soils. The ROD was for soils and sediment laden with PCBs to be dredged and disposed of off-site (Cummings Riter Consultants Inc. 2004).

Selected Remedy

The selected remedy for the Westinghouse superfund site was to remediate the groundwater, drainage ways, river sediments, and riparian soils of the Shenango River (Cummings Riter Consultants Inc. 2004). Riparian soils up to 48 inches deep having greater than ten ppm total PCBs were removed. In addition to these soils, river sediments up to 48 inches deep having greater than one ppm total PCBs were also removed. These dredged sediments and soils were disposed of properly at an offsite treatment facility and replaced with backfill. River sediments removed were estimated to be 4,100 cubic yards of PCB-filled sediments, while the riparian soils represented an estimated 300 cubic yards of PCB-contaminated soil. The riparian soils were also revegetated.

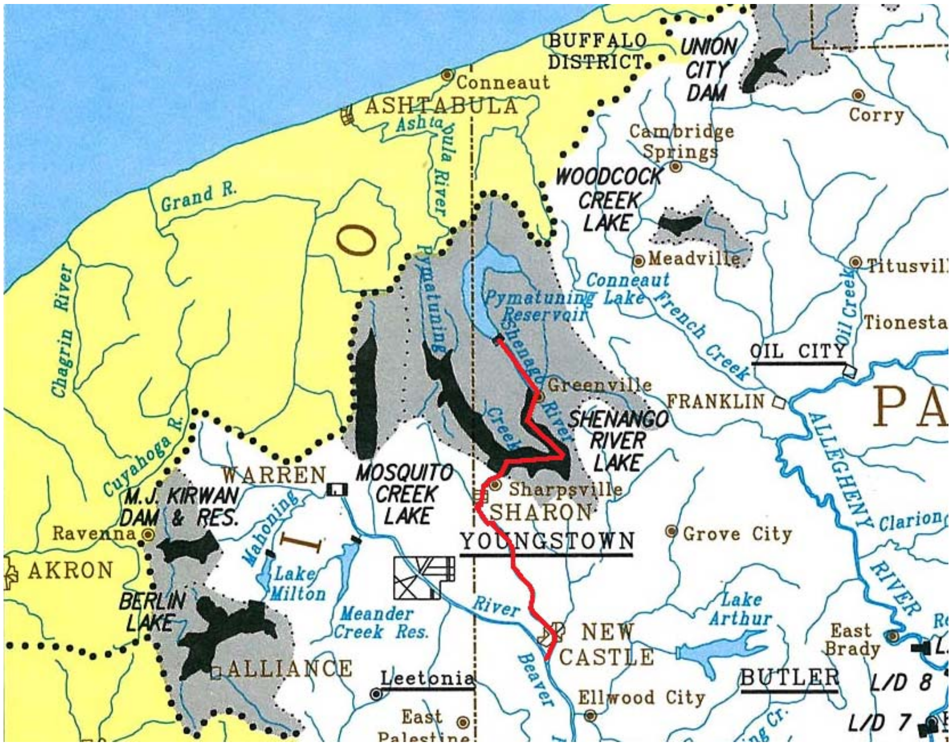
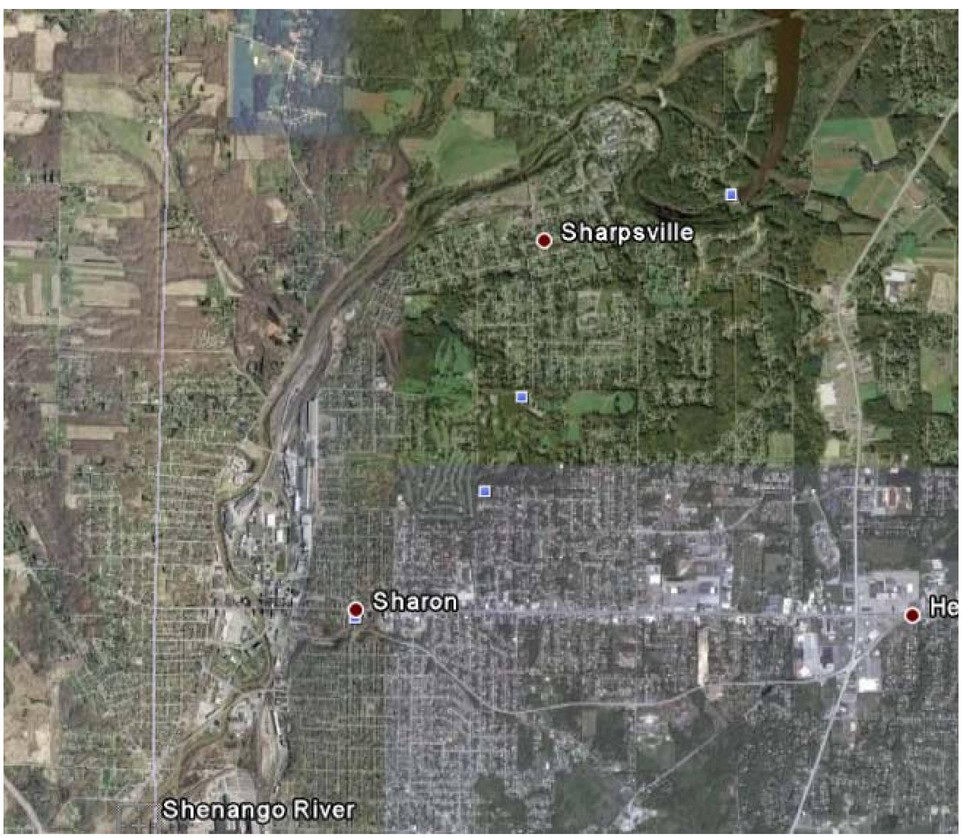


Figure 1.0 Regional map showing the Shenango River in red.



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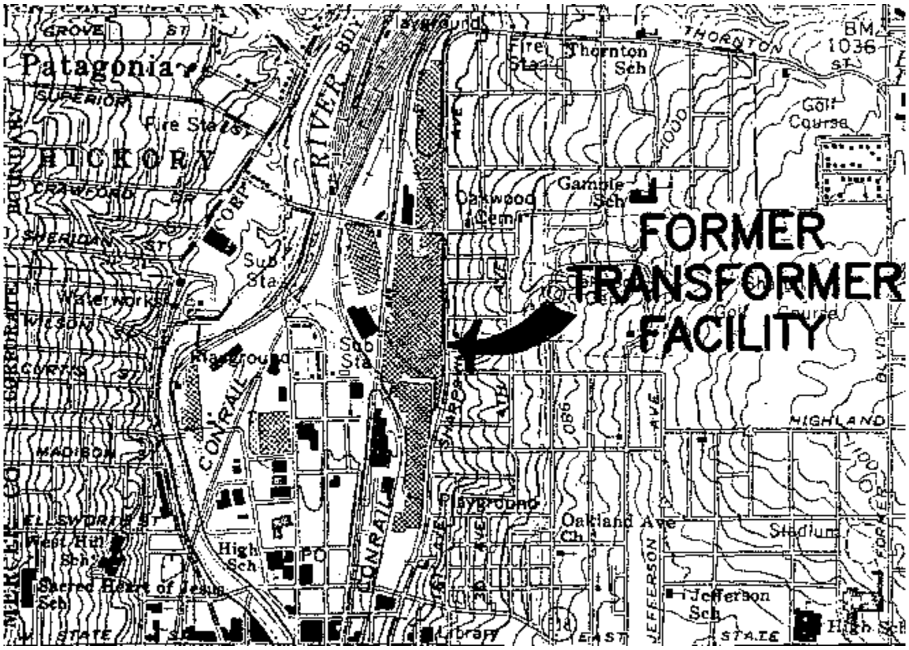

Figure 1.2 The Westinghouse Plant located along the Shenango River. (Cummings Riter Consultants Inc. 2004).

Figure 1.3 Shenango River Westinghouse Superfund Site. (Google Earth)

Remedial Objectives

The Remedial action objectives for the record of decision was to get rid of exposures to ecological receptors by removing river sediments that are greater than one milligram per kilogram of total PCBs, focusing on areas near the Clark Street outfall and Aqua Pennsylvania. Remediation efforts also seek to mitigate the fish consumption advisory in this section of the river until it can be completely removed.

The record of decision states that there may be risk to ecological receptors from metal contaminants, specifically zinc, at the target area of the river. Though there is a possible risk of high concentrations of metals in the Shenango River, it has been noted that these metals did not stem from to Westinghouse operations (Cummings Riter Consultants Inc. 2004).

PCBs

Polychlorinated biphenyls are man-made chemical compounds that were banned from production in 1977 as a result of their harmful effects on human and environmental health. There are 209 different PCB compounds that range from oily liquids to solids. They were commonly used as transformer fluids because of their chemical properties of being heat-resistant and nonflammable (Bazzanti et al. 1997). PCBs were used in fluorescent lighting fixtures, hydraulic oils` and transformer coolants before they were banned. PCB mixtures that were used in the Westinghouse plant, were referred to as Aroclor (ASTDR 2001, Bazzanti et al. 1997).

Many times PCBs have leaked from underground storage tanks, old transformers and other commercial products resulting in contamination of the environment. Once these chemicals get into the environment their structure allows for persistence in the environment (ASTDR 2001, Brinkman et al. 1980).

Because they are hydrophobic and have an affinity for sediment, when PCBs get into water systems they will accumulate in the sediments. Consequently, PCBs can be elevated within the benthic environment where many organisms at the bottom of the food chain reside. Under these circumstances, the degree of exposure would increase the chances that PCBs will bioaccumulate and bio-magnify, as they have been found to do (ATSDR 2001).

Bioaccumulation of PCBs has been related to an organism's fat content (Bazzanti et al. 1997). This makes consuming fish that are in PCBs contaminated waters a risk factor for humans. The most common side effects of being exposed to larger amounts of PCBs are rashes and acne while some studies have supported that exposed workers may have liver damage. The effects on human health are parallel to that of animals (ATSDR 2001).

Macroinvertebrates

Since PCBs in aquatic systems are found in sediments it would be make sense to assess the biota that would be in closest contact with such contaminants. Based on these characteristics (and the general use of aquatic macroinvertebrates to assess environmental stress), macroinvertebrates could be used to gauge the effects of PCBs and other potential stressors on the environment at the Shenango River Westinghouse Superfund Site.

These aquatic invertebrates make up a large biological community in the benthos of lentic and lotic systems. Being near the bottom of the food chain and being a large biological community, other organisms like birds and fish often feed on them. These aquatic insects are excellent indicators of ecosystem health because of their intimacy with the sediments, their varying ranges of tolerance to different pollutant concentrations (USEPA Biological 2007) and their presence in almost all aquatic systems.

Because macroinvertebrates live in the benthos of aquatic systems they are placed in direct contact with pollutants like heavy metals, PAHs, PCBs, other organics and inorganics that are associated with river, stream and lake sediments. These aquatic insects frequently feed on other insects, organics and other matter that reside in the benthos. Some benthos dwelling organisms frequently feed on the sediments themselves and are referred to as detrivores.

Plecoptera (Stoneflies) and Ephemeroptera (Mayflies) are considered pollution sensitive organisms, whereas, Odonata (Dragonflies) and Trichoptera (Caddisflies) are moderately tolerant to pollutants and Chironomids and Oligocheates are considered quite pollution tolerant taxa (USEPA Biological 2007). This is a useful environmental assessment tool because a population of pollution tolerant taxa would be an indication of environmental stress. More specifically, a tolerance index value for a site can be produced, giving a value that relates to the degree of stress on an aquatic system (Mandaville 2002).

Aquatic macroinvertebrates are important organisms for assessment of watershed quality due to their limited mobility, ease of collection, long residence in the aquatic system and the fact that they can readily be preserved and taken to the lab for identification (USEPA Biological 2007). Macroinvertebrates have been used to assess water quality in ecosystems including streams (Banks et al 2007, Ferrington et al 2005), lakes (MacDonald et al 2006, Jeyasingham et al 1997) and rivers (Diggins et al 1998).

Common assessments using macroinvertebrates are done using richness and abundance of Ephemeroptera, Plecoptera and Trichoptera (EPT), Ephemeroptera, Trichoptera and Odonata (ETO), and chironomids. Besides the typical richness and abundance assessments, there are also tolerance indices done on current macroinvertebrate populations. These tolerance values indicate the organism's ability to survive and reproduce in the presence of stressors (Bressler et al. 2006)

Another type of assessment that is commonly used is chironomid morphological deformity incidence rate, usually by assessing the genera *Chironomus* (Chironominae) or *Procladius* (Tanypodinae) (De Bisthoven et al. 2003). These deformities can occur while the organism is developing in a wide range of environmental conditions (MacDonald et al. 2006). These types of studies are good for rapid assessment of the current state of the aquatic system (De Bisthoven et al. 2003).

Macroinvertebrate studies often use multiple measures of assessment such as the study Chironomidae fauna in three small streams of Skania, Sweden, by De Bisthoven et al. in 2003 that used a tolerance index with a chironomid deformity incidence as a supplement.

Objectives

There are multiple objectives of this study that will ultimately help characterize and describe the nature of stress at the Shenango River Westinghouse Superfund site: (1) Take macroinvertebrate samples and identify species abundance, richness and use the presence of specific organisms to assess the superfund site as a whole, (2) Use macroinvertebrate population to determine a tolerance index for the entire site in addition to the different site areas, (3) Assess the Chironomid genus *Chironomus* for mentum deformities and (4) Use previous objectives to compare the dredged areas (remediated) to the non-remediated areas along the Westinghouse Superfund site of the Shenango River.

Chapter II Methods

Sampling

Samples were taken with respect to where the Shenango River was dredged during the superfund cleanup; starting from downstream and working up stream (Figure 2.0). Sampling was done on three separate dates representing three different seasons to ensure collection of all possible macroinvertebrates some of which emerge synchronously and could be missed by a single sampling effort. Landmarks and aerial photographs were used to mark each of the sampling locations for repetition.

The first sampling date (September 18th of 2007) yielded only twelve samples, six from two remediated areas combined and six from the channel. Samples were not taken at the uppermost remediated site due to its having large cobble substrate that was impossible to sample with the petite ponar. The upper most non-remediated site also did not yield samples, due again to our inability to use a ponar grab in its large cobble substrate.

The second sample date (November 13th of 2007) yielded fifteen samples; six from remediated sites, six from non-remediated sites and three from a potential reference site (the site upstream of the Westinghouse location, above the bridge). The sampling on this date went as planned and all proposed samples were taken with the exception of those that were previously judged not possible with the ponar grab being used.

The third date (May 13th of 2008) yielded thirteen samples; four from remediated sites, six from non-remediated sites and three from the reference site. Two samples from the most downstream sampling site were unable to be obtained due to unsuitable substrate. The challenge of this sample date was that there was a storm event that occurred in the preceding days. The increase in water velocity made it difficult to maneuver the boat and to keep it steady during the sampling process.

To obtain water chemistries and macroinvertebrate samples, a flat boat was used to get onto the Shenango River where samples will be collected. Once at the macroinvertebrate sampling location, a probe was used to measure dissolved oxygen, conductivity, temperature, specific conductivity from just above the sediment level. A second probe was used to collect pH from just below the water's surface for each of the sampling sites.

Collection of macroinvertebrates was done by using a petite ponar and sampling method as established by the Environmental Protection Agency. Once a macroinvertebrate sample was obtained from the river it was immediately filtered using a 500 micron screen (Ohio Environmental Protection Agency 2006). Matter remaining in the screen was placed into a one gallon zip lock bag labeled with the sampling date, location and number. These bags were stored in a cooler for transportation back to the lab for separation and identification.

Macroinvertebrate Preparation and Identification

At the lab, 70% ethanol was added to each sample, for preservation, before placing them in a fridge (Ohio Environmental Protection Agency 2006). To begin the macroinvertebrate separation, a sample bag was emptied into a 500 micron screen filter to remove any residual silts and clays. Once filtered, the contents remaining in the micron filter were emptied into a white enamel pan for organism separation. Organisms were picked out using forceps and a magnifying lens and placed into a petri dish containing

70% ethanol. The organisms were separated and placed respectively into preservative filled vials labeled oligocheates, dipterans and other for further identification.

Juvenile stages of Trichoptera (Caddisflys), Plecoptera (Stoneflys), Ephemeroptera (Mayflys), Odonata (Dragonflys) and others were identified and quantified to lowest feasible taxonomy, usually genus.

Chironomids were identified based on their mentum and other head capsule characteristics. To do this their head capsules were first severed from their bodies and placed into 10% KOH solution (Ohio Environmental Protection Agency 2006). They were placed in this solution and warmed below boiling until the head capsules were adequately cleared of debris. Once cleared, the head capsules were placed ventrally on a slide. Canadian balsam was then placed on a cover slip and carefully adhered over the head capsule and to the slide. Slides were labeled with sampling date, location, which sample and which slide for that particular sample. Two specimens were place on a slide; the closest specimen to the frosted end labeled “a” and the specimen farther from the frosted end of the slide labeled “b” to differentiate specimens. While identifying midges to genus level, they were assessed for mentum deformities for a more thorough analysis of the environmental stress (Ohio Environmental Protection Agency 2006).

Generally, aquatic worms are not identified to a level more specific than Class. Because of this, these worms were not identified past the Oligochaeta level (Ohio Environmental Protection Agency 2006). Due to the susceptibility of aquatic worm specimens to be pulled and torn apart in the sampling and sorting process, oligocheates were quantified by counting the number of end pieces and dividing that number by two (Ohio Environmental Protection Agency 2006).

Analysis

A tolerance index value is calculated based on the Mandaville publication in 2002 "Benthic Macroinvertebrates in Freshwaters - Taxa Tolerance Values, metrics, and Protocols." Mandaville (2002) uses an updated and modified Hilsenhoff taxonomic value key and tolerance index. This tolerance index gives a value to each organism on a scale from 0 (intolerant) to 10 (tolerant) (Mandaville 2002). This is on the premise that pollution sensitive organisms will not be present in pollution stressed aquatic environments. Averaging all the organisms' values gives an average tolerance value for the entire system, revealing the degree of stress on that given environment (Mandaville 2002).

It has been documented that it is important to use a biotic index that is genus/species specific rather than a broader family level index (Mandaville 2002). "Mandaville (2002) suggests a genus/species-based index I preferable to a broader family-based measure. Taxa within families often vary widely in pollution tolerance, so a family-wide tolerance value may not reflect the actual pollution tolerance of the individual taxa collected."

Multivariate analysis of variance (MANOVA) was the chosen method of statistical analysis and was run on the variables "site type" and "date" using SPSS (SPSS 13.0). The dependant variables in the analysis were abundance, richness and tolerance index. The Wilks' lambda statistic is most commonly used MANOVA statistic and therefore is the statistic being resulted in this study (SPSS 13.0).

A MANOVA was performed on the data that included the reference site and run again on the data where the reference site was incorporated into the non-remediated sites. This was done to see if the data would then yield a significant difference between the remediated and nonremediated sites.

When these analyses were run, a Levene's test for homogeneity of variances was also run to see if there are equal variances in the data (SPSS 13.0). The abundance values for all organisms and abundance values for chironomids were heteroscedastic. Because of this, all abundance values were Log X+1 transformed. A Levene's test on the log transformed abundance data showed that the data is now homoscedastic. It is possible to see how the Poisson distributed abundance data become normally distributed after the transformation by looking at Figures 1.0 and 1.1.

The richness for all data and all tolerance index values were all homoscedastic and therefore not transformed.

A MANOVA was again performed on data that included the reference site in addition to the data where the reference site was incorporated into the non-remediated sites (SPSS 13.0).

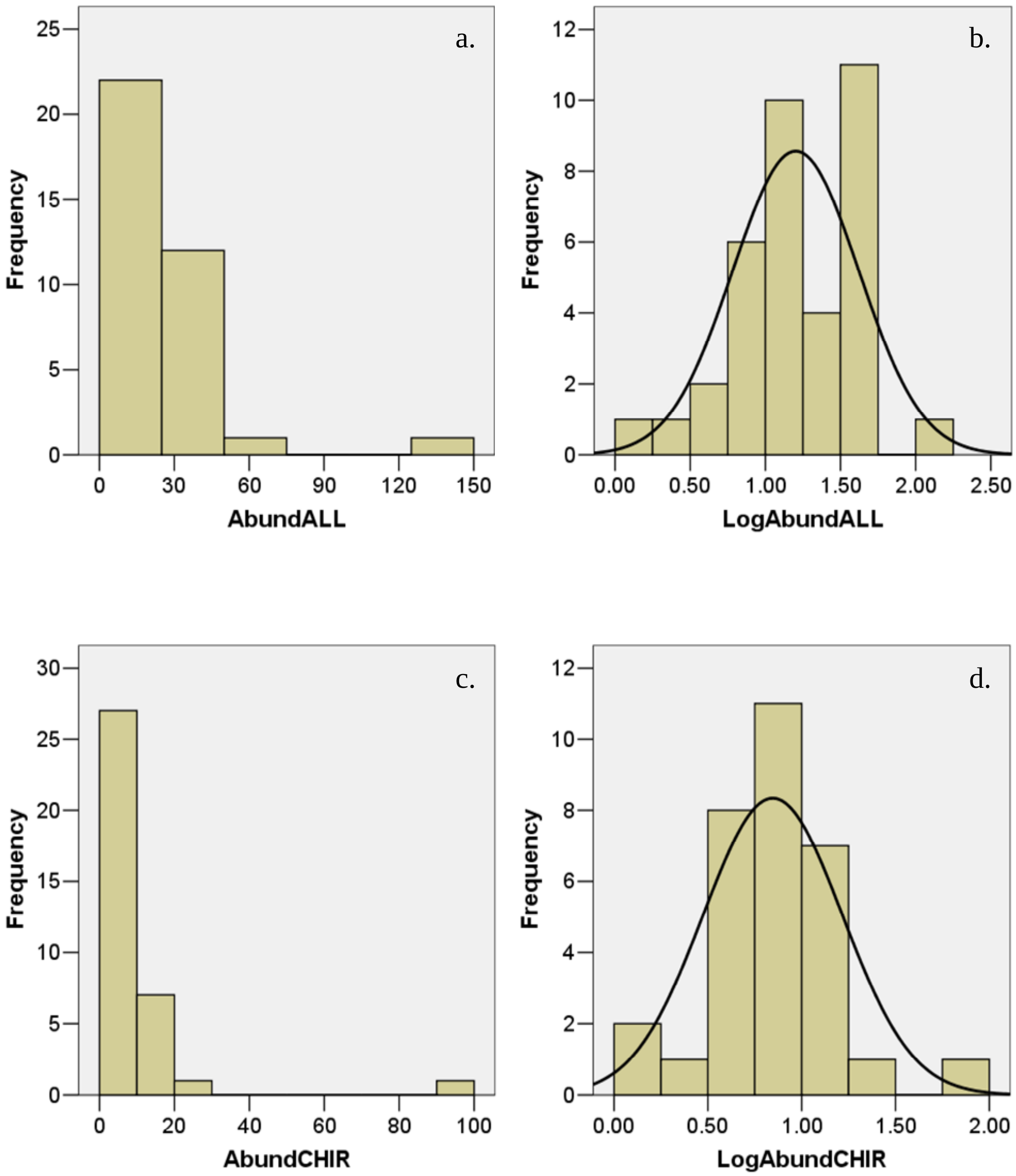

Figure 2.0 Histogram of abundance of all organisms (a.) compared to the log X+1 transformation of abundance of all organisms (b). Histogram of chironomid abundance (c.) compared to the log X+1 transformation of chironomid abundance (d).

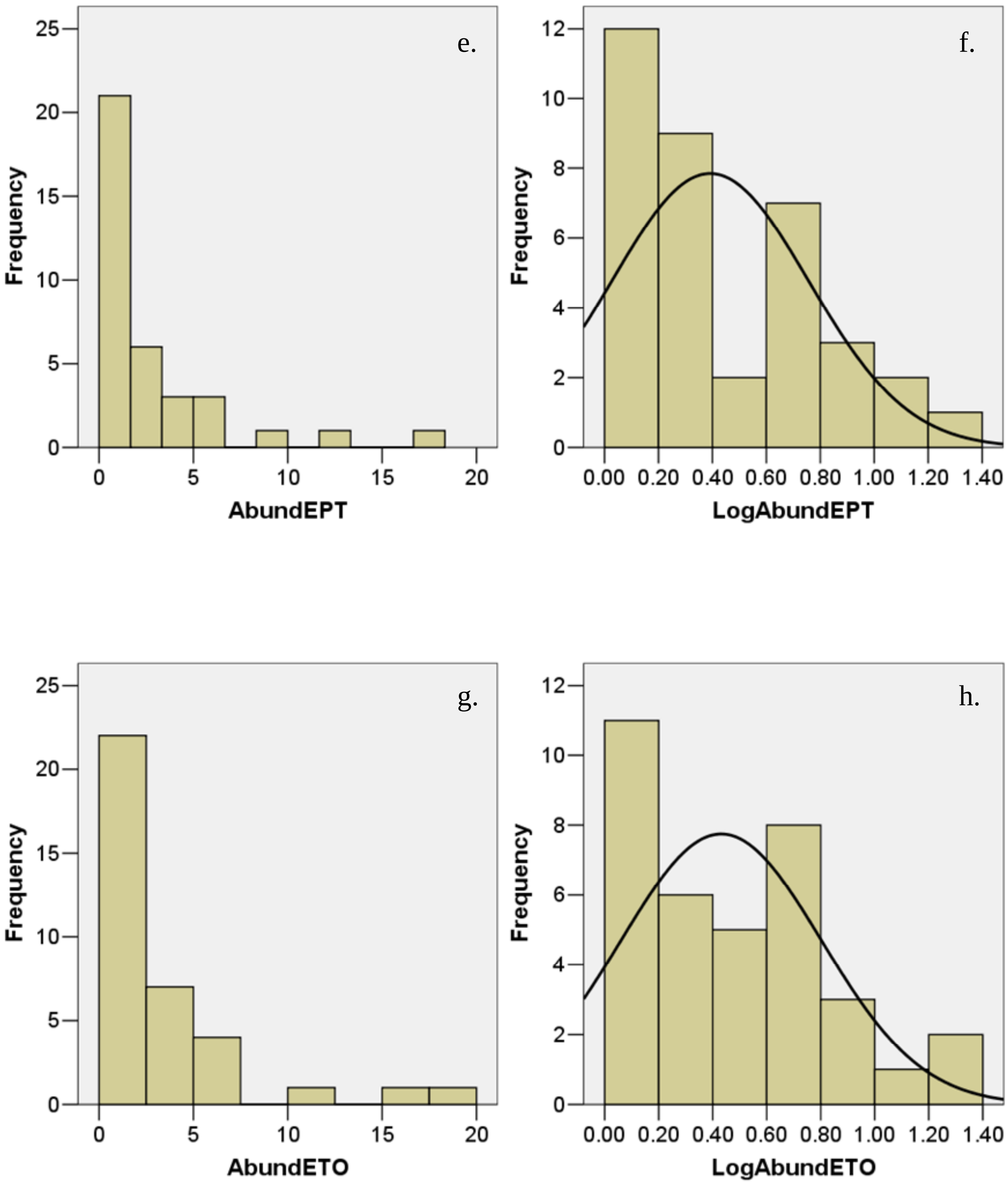

Figure 2.0 (cont.) Histogram of abundance of EPT (e.) compared to the log X+1 transformation of abundance of EPT (f.). Histogram of ETO abundance (g.) compared to the log X+1 transformation of ETO (h.).

Chapter III Results and Discussion

Richness and Abundance

The number of taxa, or richness, is 35 for total taxa, 6 EPT taxa, 12 ETO taxa and 16 different chironomid taxa. The abundance of all organisms at our study site is 712.7 organisms per square meter, 73.1 EPT per square meter, 111.3 ETO per square meter and 232.9 chironomids per square meter. Abundance and richness values with standard eorr values can be found in Appendix D. A complete list of taxa and number of organism can be found in Appendix C. Based on water chemistry values in Appendix B, dissolved oxygen was not a limiting factor on abundance or richness values.

It is possible that abundance and richness numbers are depressed which could be explained by the location of the site being in an urbanized area. It has been documented that macroinvertebrate abundance and species diversity is inversely proportionate to urbanization (Beasley 2002, Gray 2003). Increased urbanization results in a decrease species richness and abundance (Beasley 2002, Gray 2003). Increased urbanization's means increased impervious areas i.e. roofs, roads and parking lots (Gresens 2007). Impervious area destroys aquatic ecosystems is by altering the hydrology of urban areas, causing erosion and pollution.

Other consideration should be giving to the possibility of the landfill superfund, located upstream of the Westinghouse Superfund Site, influencing the information gathered from this study. The upstream landfill superfund site, known as the River Road Landfill, is located two miles northeast of Sharon, PA. (USEPA 2009) The Shenango River is the southern boundary of the landfill which makes its leachate a cause for concern. From 1982 to 1985 the landfill received PCBs contaminated sludge before it was capped in 1987. (USEPA 2009)   Besides PCBs and before 1980, the landfill accepted industrial, municipal and residential wastes, all of which could influence the reference, remediated and non-remediated samples taken at the Westinghouse Superfund Site. (USEPA 2009)   The landfill is remedying these potential problems by using a fence, solid waste cap, a groundwater damn, a groundwater/leachate collection and monitoring program. (USEPA 2009)

Deformity Incidence

The total deformities including all sites are 6 out of a total of 107 *chironomus* genera assessed giving an overall deformity percentage of 5.6%. The deformities in the nonremediated areas are 1 out of 17 *chironomus* assessed a deformity percentage of 5.9%. The remediated sites had a total of 4 deformities out of 64 *chironomus* assessed, a deformity percentage of 6.3%. The reference site totaled 26 *chironomus* and has 1 *chironomus* deformity giving it a deformity percentage of 3.8%. An example of a chironomus mentum without deformities can be seen below in figure 4a while an example of a deformed mentum can be seen in figures 4b and 4c.

An overall deformity incidence of 5.6 % for the genus *chironomus* could indicate environmental stress on the Westinghouse Superfund Site section of the Shenango River. Based on a background incidence study on Canadian Laurentian Great Lakes, any incidence greater than 2.1% *chironomus* deformity rate is considered high based on their study (Burt et al. 2003). Though a baseline deformity rate has been established, it is still possible that the Westinghouse Superfund Site, with a slightly elevated tolerance index, is not a heavily stressed environment. Another study had incidence rates between <4% to

8% for sites that were believed to not have any sources of contamination whereas another site receiving municipal sewage effluent had a deformity incidence rate of 15% (MacDonald et al. 2005). The heavily industrialized Buffalo River had *chironomus* deformities occurring in 29% of specimen (Diggins et al. 1993).

It is impossible to determine whether or not the Westinghouse Superfund site is above or below the baseline. Though a background incidence is not officially determined, it is still possible to understand where the site is with respect to environmental stress by comparing it to other deformity incidence. The incidence rates cited are much higher than what is found at the Westinghouse site in the Shenango River which suggests that the Shenango River is not nearly as environmentally stressed as these other aquatic systems. It is likely that the Shenango River is lightly stressed, yet is not nearly as stressed an environment as the Buffalo River. This could also indicate different types and sources of contamination present.

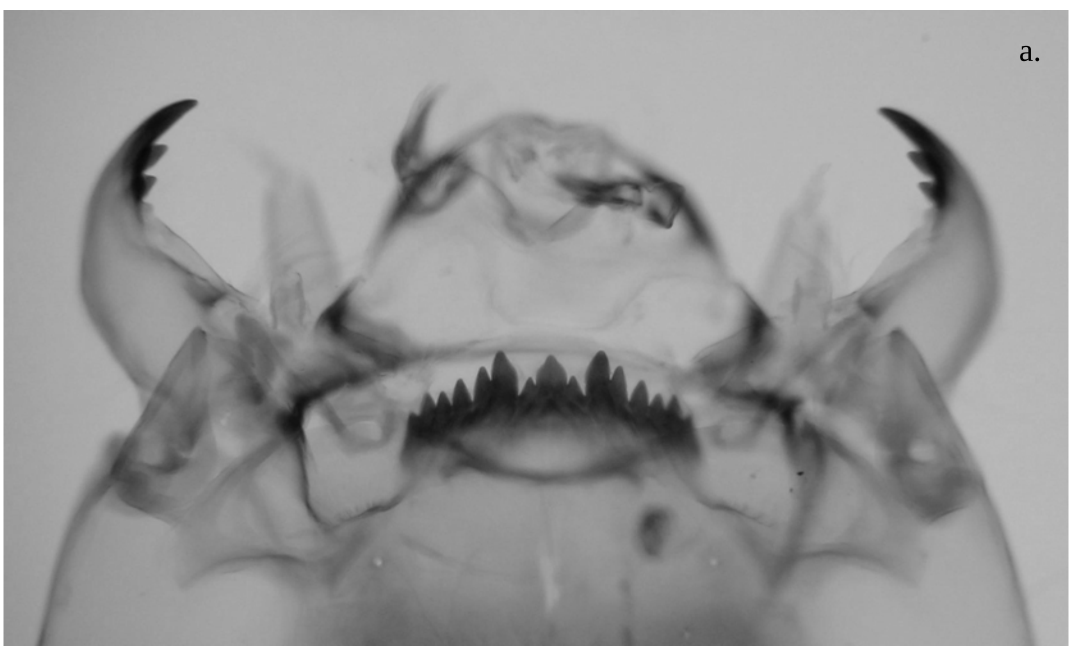

Figure 3 a.) Chironomid *chironomus*, no deformities. b.) Deformed Chironomid *chironomus*, medial gap. c.) Deformed Chironomid *chironomus*, missing left medial tooth, gap in mentum, missing medial tooth.

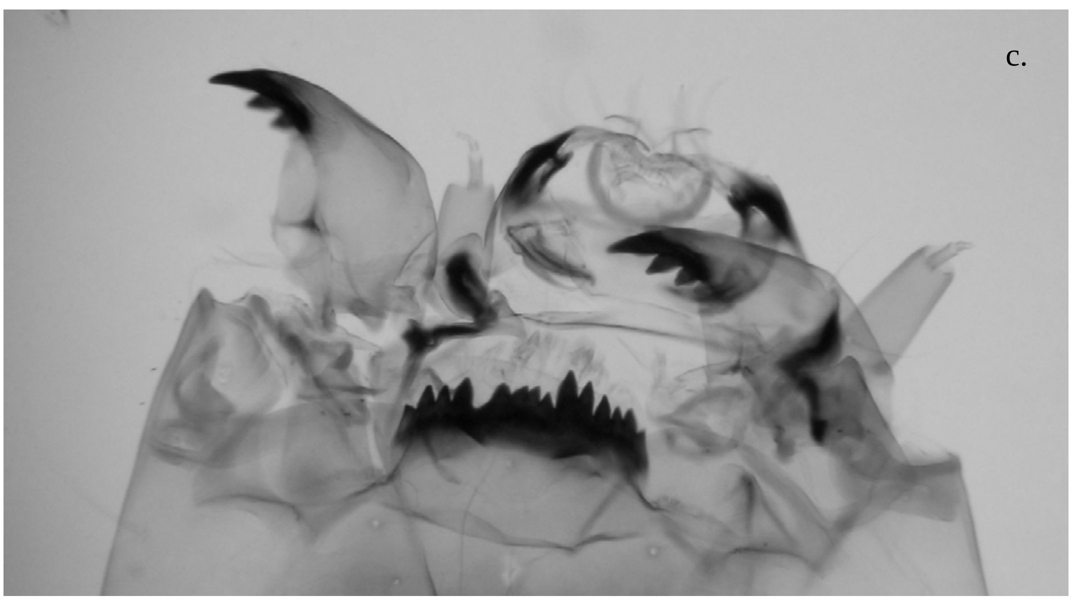

Figure 3 (cont.) a.) Chironomid *chironomus*, no deformities. b.) Deformed Chironomid *chironomus*, medial gap. c.) Deformed Chironomid *chironomus*, missing left medial tooth, gap in mentum, missing medial tooth.

Tolerance Index

The total tolerance index for all sites is 5.6. The tolerance index value for the remediated areas is 5.4. The tolerance index value for the non-remediated area is 5.2. The index value for the reference site is 6.1. A visual comparison can be seen below in Figure 5. An interpretation of these tolerance values can be found in Appendix A.

The reference site value is considered fair water quality meaning that fairly significant organic pollution is likely. This tolerance index is not only informative about possibly organic pollution but can also reveal possible effects of impoundment, thermal pollution and some chemical pollution (Hilsenhoff 1998).

Being that the reference site is upstream of the entire Westinghouse site and is consistent with the other sampling sites in being moderately stressed, it should be considered that the stress on the environment is coming from an upriver source or sources. Another consideration for these tolerance index values is a decline in intolerant species due to urban runoff. It has been found that urban stretches of rivers had fewer sensitive species than non-urban areas due to physical and chemical changes as a result of urban runoff (Gray 2004). Once again, the River Road Landfill should be considered as an influence on these tolerance index values.

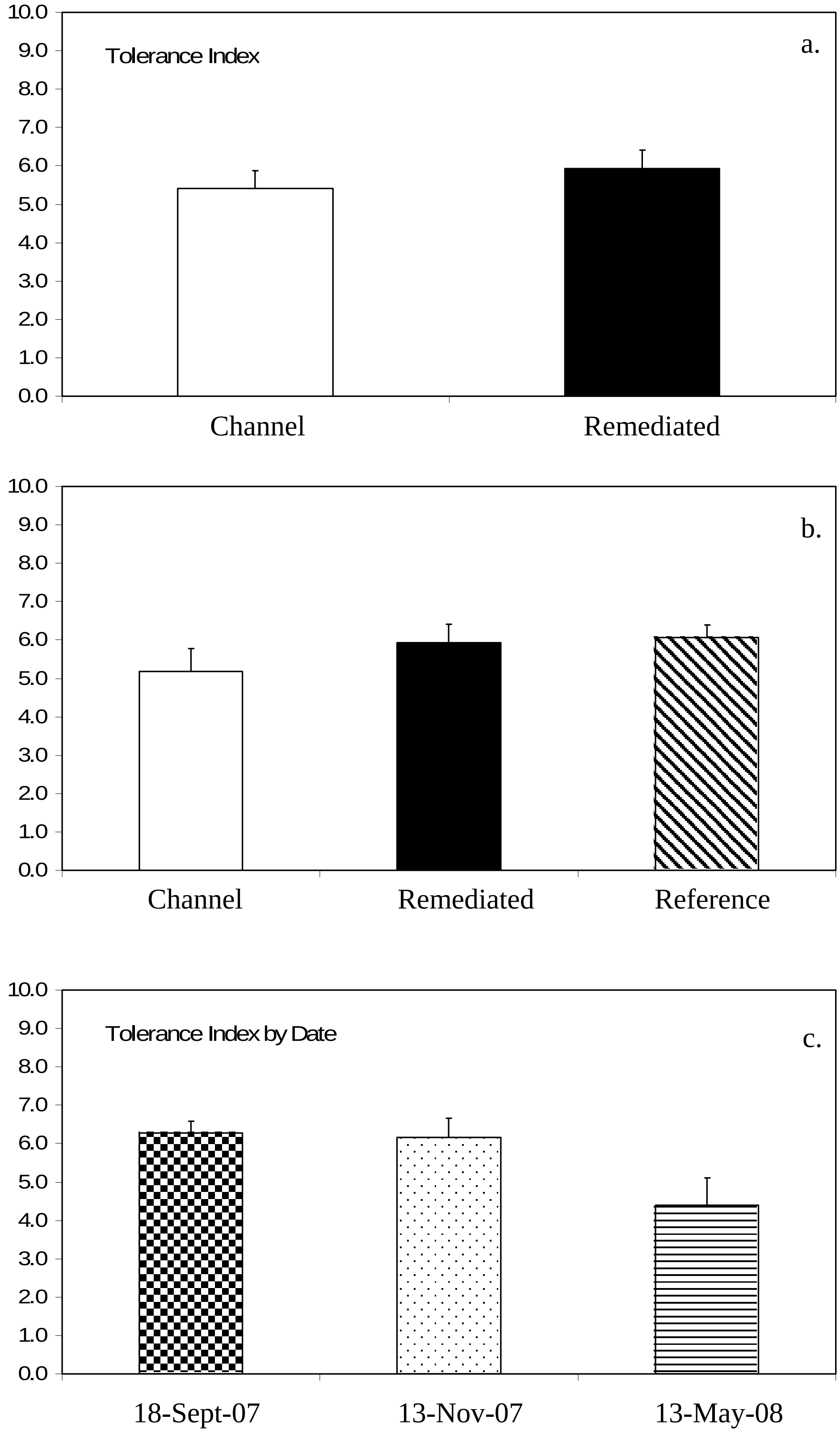

Figure 4 Tolerance index by a.) Non-remediated v. Remediated site. b.) Non-Remediated v. Remediated v. Reference site. c.) Date.

Richness and Abundance and Tolerance Index Analysis

Site Type with Reference Site

The "site type" including the reference site was not significant with a Wilks' Lambda significance of 0.827. Based on this statistic, the remediated, channel and references sites are all have similar richness, abundance and tolerance index values. This result supports the null hypothesis. The similarity between sites can be seen in Figure 3.

Site Type without Reference Site

The results of the MANOVA for "site type" when the reference site was combined with the other channel sites gave a Wilks' Lambda significance of .966. As when sites above the Clark Street Bridge were considered a reference site, the null hypothesis was supported and the remediated sites were not significantly different from non-remediated areas with respect to their richness, abundance and tolerance index. The Similarity between these sites can be seen below in Figure 3.1.

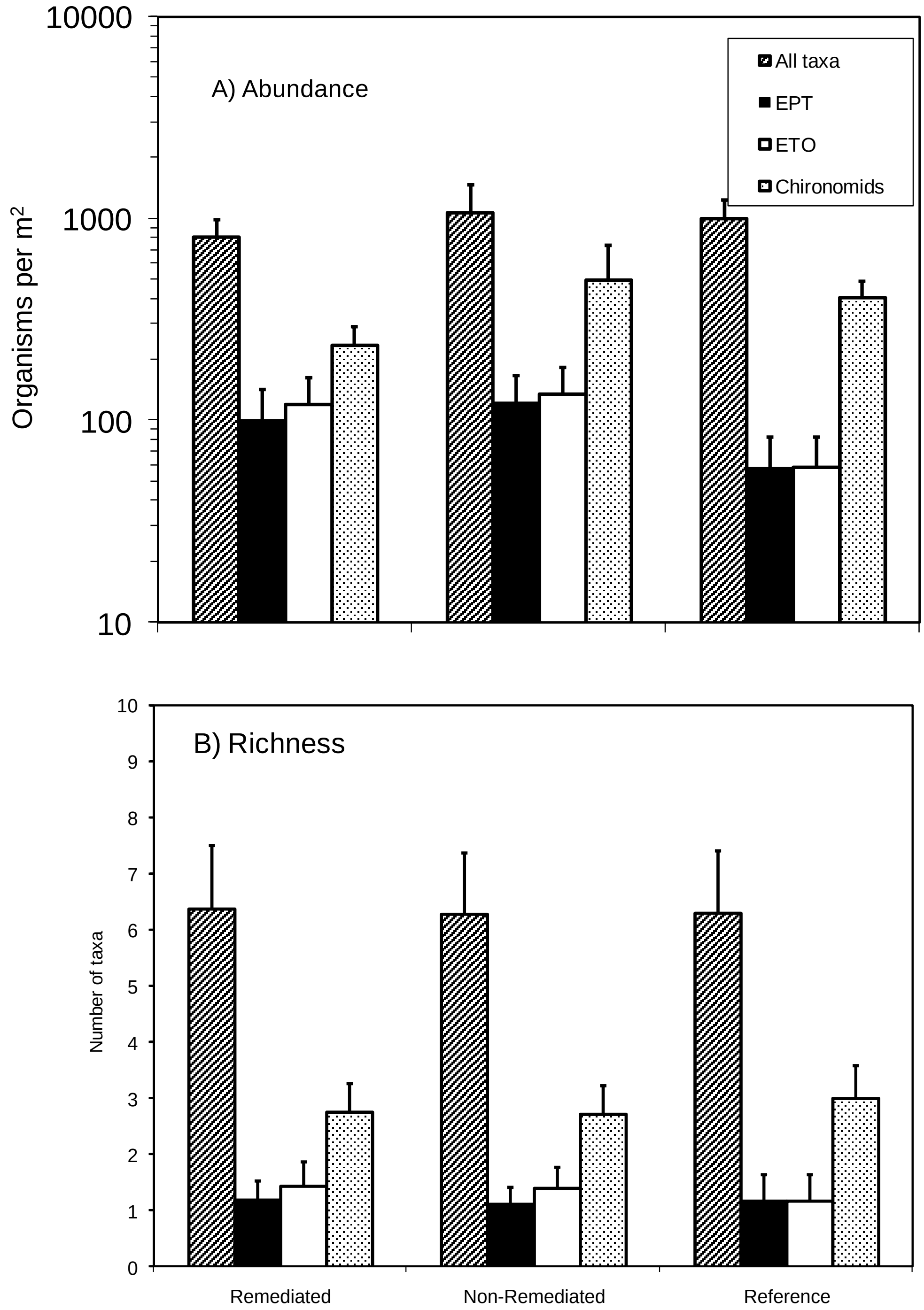

Figure 5 A.) Remediated v. Non-Remediated v. Reference site bar graph comparison of abundance of all organisms, Chironomids, EPT and ETO by site. B.) Remediated v. Non-Remediated v. Reference site bar graph comparison richness of all organisms, Chironomids, EPT and ETO by site.

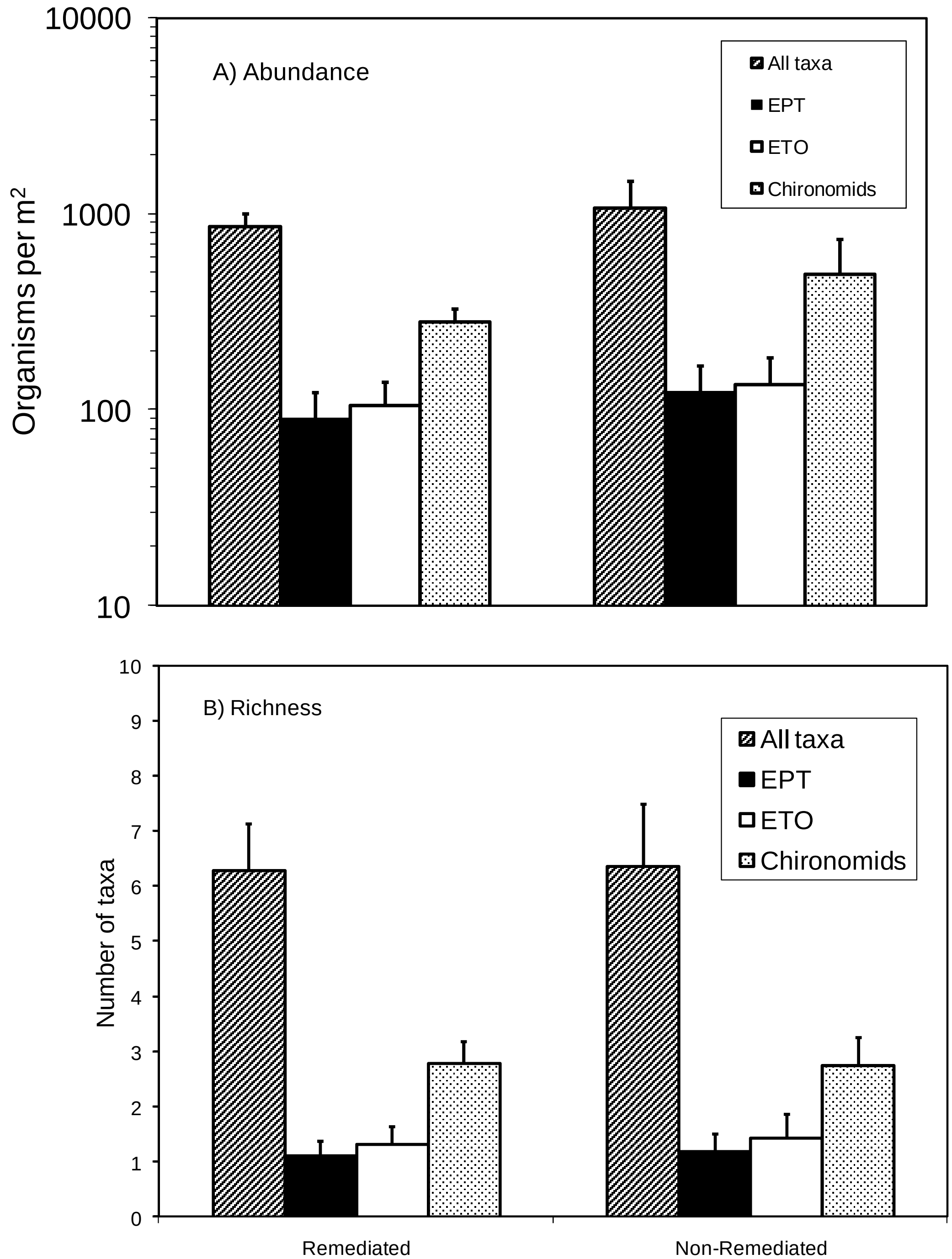

Figure 5.1 A.) Remediated v. Non-Remediated bar graph comparison of abundance of all organisms, Chironomids, EPT and ETO. B.) Remediated v. Non-Remediated bar graph comparison of richness of all organisms, Chironomids, EPT, ETO.

Date with Reference Site

Richness of all organisms differed significant between the second and third sampling dates. Richness of chironomids is significant between the first and second sampling dates. The abundance of all organisms is significant between the second and third sampling dates. Lastly, chironomid abundance is significant between the first and second sampling dates. The differences in abundance and richness can be seen below in Figure 3.2 The reason for differences between the second sampling date and the others can be attributed to two facts: There is less chironomid emergence, the most abundant taxa, in winter temperatures as in the second sampling date in November; The other factor giving more abundance and richness to the second sampling date would be that it had more samples taken (15) compared to the first (12) and second (13) sampling dates. More samples give a greater abundance of organisms and would yield a greater chance at having more taxa. The most likely cause for differences among sample dates is the phenology of macroinvertebrates.

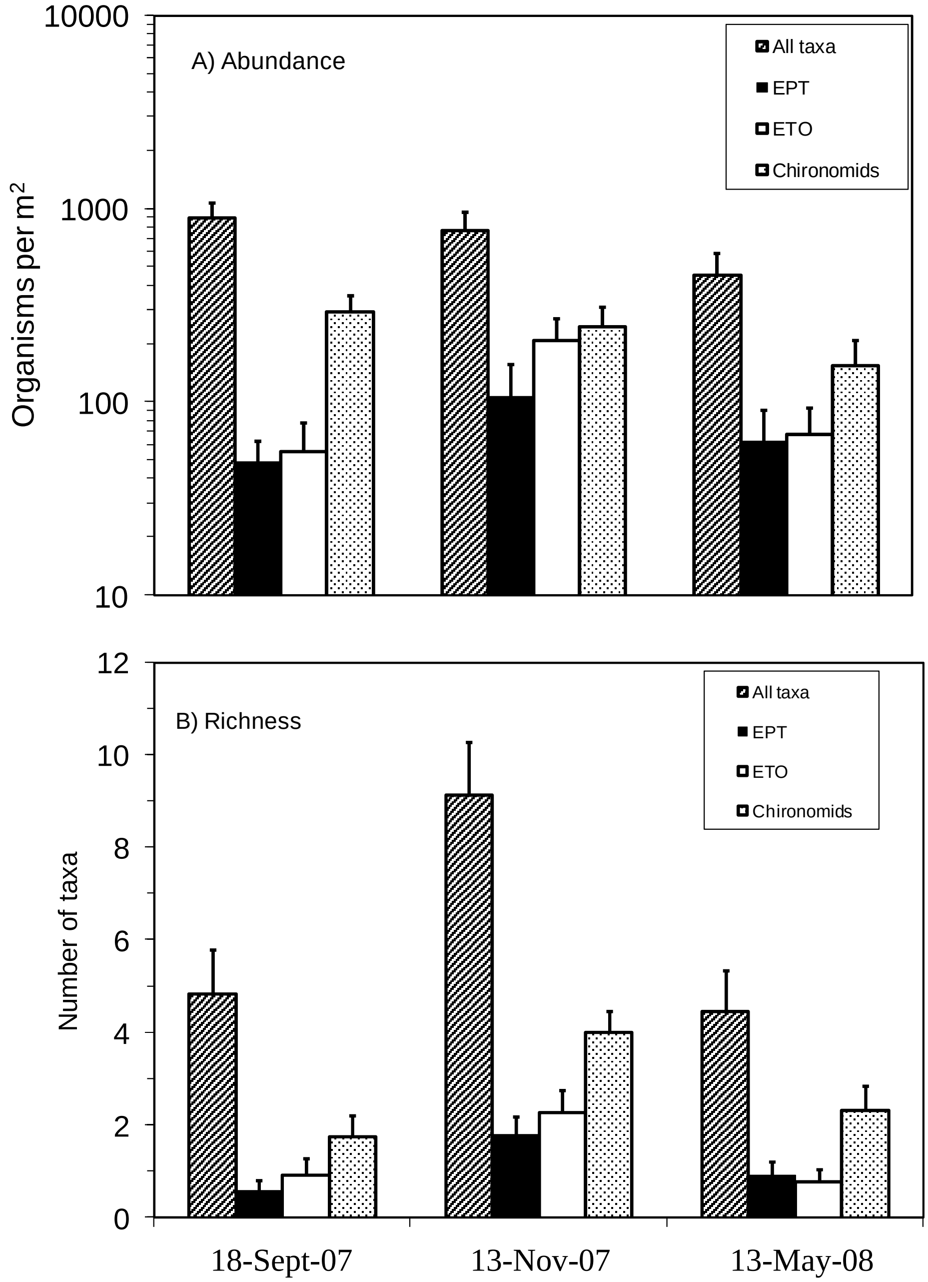

Figure 5.2 A.) Date comparison of bar graphs for abundance of all organisms, Chironomids, EPT, ETO. B.) Date comparison of bar graphs for richness of all organisms, Chironomids, EPT, ETO.

Chapter IV Conclusion

The Westinghouse Superfund site displaying a possible low but above normal chironomid deformity incidence and a moderate tolerance index indicates a moderately stressed environment. Since the reference site up river of the superfund is not statistically different from the other sites sampled, it can be assumed that the Westinghouse is not the primary stressor on the aquatic system. The results generated by this study are common in urban streams and rivers due to urban runoff which is one of the probable causes for the sites current stress. Another stresses on the macroinvertebrate community could be the upriver landfill.

Since there is no significant difference among the reference site, remediated sites, and channel sites, it can be said that the entire system is being influenced by not one single environmental stress but an evenly distributed stress. This stress could be from an upstream point source(s), such as the landfill, a non-point source such as urban runoff or a combination of multiple sources affecting the study.

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Appendix A

Table 1 Interpretation of Tolerance Index Ranges (Mandaville 2002)

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	Organic pollution unlikely
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution probable
5.51-6.50	Fair	Fairly substantial pollution likely
6.51-7.50	Fairly poor	Substantial pollution likely
7.51-8.50	Poor	Very substantial pollution likely
8.51-10.00	Very poor	Severe organic pollution likely

Appendix B
Table of Water Chemistries

Day 1(18SEPT07)		Remediated 1		Remeidated 2	
		DO	93.3	DO	68.5
		T	22.4	T	21.8
		Cond	227.1	Cond	226
		Cond2	199.1	Cond2	201.1
		pH	8.1	pH	8.1
Reference		**Non-Remidated 1**		**Non-Remidated 2**	
DO	N/A	DO	92.7	DO	95.6
T	N/A	T	22.3	T	22.2
Cond	N/A	Cond	227.2	Cond	226.9
Cond2	N/A	Cond2	119.4	Cond2	199.4
pH	N/A	pH	8.1	pH	8.2

Day 2 (13NOV07)		Remediated 1		Remeidated 2	
		DO	98.4	DO	99.5
		T	9.9	T	10.2
		Cond	170.5	Cond	171.1
		Cond2	188.1	Cond2	188.6
		pH	7.8	pH	8
Reference		**Non-Remidated 1**		**Non-Remidated 2**	
DO	103	DO	97.4	DO	97.3
T	10.2	T	10	T	9.8
Cond	168.9	Cond	169.7	Cond	169.5
Cond2	186	Cond2	187.7	Cond2	188.1
pH	8.1	pH	8.1	pH	7.9

Day 3 (13MAY08)		Remediated 1		Remeidated 2	
		DO	89.9	DO	89.8
		T	16.7	T	16.2
		Cond	168.2	Cond	163.6
		Cond2	191.7	Cond2	159.2
		pH	6.1	pH	6.5
Reference		**Non-Remidated 1**		**Non-Remidated 2**	
DO	88.6	DO	89.6	DO	93.2
T	17.3	T	16.9	T	16.4
Cond	166	Cond	164	Cond	161.7
Cond2	159.1	Cond2	158.5	Cond2	157.5
pH	6.6	pH	6.5	pH	6.6

Appendix C

Table of Organisms

			Class:	Oligochaeta	Malacostraca	Malacostraca	Insecta	Insecta	Insecta
			Order:		Amphhipoda	Isopoda	Ephemeroptera	Ephemeroptera	Trichoptera
			Suborder:						
			Family:		Gammeridae	Asellidae	Caenidae	Leptophlebiidae	Leptceridae
			Subfamily:						
			Tribe:						
			Genus:				Caenis	Neochoroterpes	Oecetis
Tolerance Value				**5**	**4**	**8**	**7**	**4**	**5**
Site	**Date**	**Rep.**							
CH2	1	1		4	0	0	0	0	1
CH2	1	2		7	0	0	0	0	0
CH2	1	3		6	0	0	0	1	0
CH2	2	1		7	3	0	2	0	1
CH2	2	2		12	9	0	8	1	4
CH2	2	3		4	17	1	1	0	0
CH2	3	1		0	0	0	0	0	0
CH2	3	2		2	0	0	0	1	2
CH2	3	3		0	0	0	0	0	0
CH3	1	1		10	0	0	0	0	0
CH3	1	2		7	0	0	0	0	0
CH3	1	3		0	0	0	0	0	0
CH3	2	1		5	0	0	0	0	0
CH3	2	2		4	3	1	4	0	0
CH3	2	3		0	1	0	0	1	0
CH3	3	1		1	4	0	1	3	0
CH3	3	2		0	0	0	0	0	0
CH3	3	3		1	0	0	1	3	0
Ref.	2	1		14	13	0	1	0	1
Ref.	2	2		14	0	0	0	0	0
Ref.	2	3		5	9	0	1	0	2
Ref.	3	1		6	2	0	0	0	0
Ref.	3	2		1	2	0	1	0	0
Ref.	3	3		1	0	0	0	0	0
3	2	1		2	0	0	1	0	0
3	2	2		1	3	0	0	0	0
3	2	3		0	0	0	0	0	0
3	1	1		1	0	0	0	0	0
3	1	2		2	0	0	0	0	0
3	1	3		2	0	0	0	0	1
3	3	1		0	17	0	2	0	1
2	1	1		7	0	0	2	4	0
2	1	2		4	0	0	0	0	0
2	1	3		1	0	0	0	0	0
2	2	1		14	2	0	5	0	0
2	2	2		9	22	8	7	2	1
2	2	3		5	5	0	3	5	1
2	3	1		7	0	0	0	0	0
2	3	2		0	2	0	1	0	0
2	3	3		8	5	0	0	0	0

			Class:	Insecta	Insecta	Insecta	Insecta	Insecta
			Order:	Trichoptera	Trichoptera	Trichoptera	Odonata	Odonata
			Suborder:				Anisoptera	Anisoptera
			Family:	Hydropsychidae	Hydropsychidae	Polycentropodidae	Gomphidae	Gomphidae
			Subfamily:					
			Tribe:					
			Genus:	Diplectrona	Smicridea	Neurclipsis	Aphylla	Stylurus
Tolerance Value				**5**	**5**	**7**	**5**	**4**
Site	**Date**	**Rep.**						
CH2	1	1		0	0	1	1	0
CH2	1	2		1	0	0	1	0
CH2	1	3		0	0	0	0	0
CH2	2	1		0	0	0	0	2
CH2	2	2		0	1	3	0	1
CH2	2	3		0	0	0	0	0
CH2	3	1		0	0	0	0	0
CH2	3	2		0	0	0	0	0
CH2	3	3		0	0	0	0	0
CH3	1	1		0	0	0	0	0
CH3	1	2		0	0	0	0	0
CH3	1	3		0	0	0	1	0
CH3	2	1		0	0	0	0	0
CH3	2	2		0	0	0	0	0
CH3	2	3		0	0	0	0	0
CH3	3	1		0	0	0	0	0
CH3	3	2		0	0	0	0	0
CH3	3	3		0	0	0	0	0
Ref.	2	1		0	1	0	0	0
Ref.	2	2		0	0	0	0	0
Ref.	2	3		0	0	0	0	0
Ref.	3	1		0	0	1	0	0
Ref.	3	2		0	0	0	0	0
Ref.	3	3		0	0	0	0	0
3	2	1		0	0	1	0	0
3	2	2		0	0	1	0	0
3	2	3		0	0	0	0	0
3	1	1		0	0	0	0	0
3	1	2		0	0	0	0	0
3	1	3		0	0	0	1	0
3	3	1		0	0	3	0	0
2	1	1		0	0	0	0	0
2	1	2		0	0	0	0	0
2	1	3		0	0	0	0	0
2	2	1		0	0	1	0	0
2	2	2		0	0	3	0	0
2	2	3		0	0	0	0	0
2	3	1		0	0	0	0	0
2	3	2		0	0	0	0	0
2	3	3		0	0	0	0	0

			Class:	Insecta	Insecta	Insecta	Insecta	Insecta
			Order:	Odanata	Odanata	Odanata	Odanata	Coleoptera
			Suborder:	Anisoptera	Zygoptera	Zygoptera	Zygoptera	
			Family:	Cordnliidae	Coenagrionidae	Coenagrionidae	Lestidae	Elmidae
			Subfamily:					
			Tribe:					
			Genus:	Macromiinae	Argia	Enallagma	Lestes	
Tolerance Value				**5**	**6**	**8**	**6**	**4**
Site	**Date**	**Rep.**						
CH2	1	1		0	0	0	0	1
CH2	1	2		0	0	0	0	1
CH2	1	3		0	0	0	0	0
CH2	2	1		0	0	0	0	2
CH2	2	2		0	0	0	0	2
CH2	2	3		0	0	0	1	5
CH2	3	1		0	0	0	0	0
CH2	3	2		0	0	0	0	0
CH2	3	3		0	0	0	0	0
CH3	1	1		0	0	0	0	0
CH3	1	2		0	0	0	0	0
CH3	1	3		0	0	0	0	0
CH3	2	1		0	0	0	0	1
CH3	2	2		0	0	0	0	3
CH3	2	3		0	0	1	0	0
CH3	3	1		0	0	0	0	1
CH3	3	2		0	0	0	0	0
CH3	3	3		0	0	0	0	0
Ref.	2	1		0	0	0	0	1
Ref.	2	2		0	0	0	0	4
Ref.	2	3		0	0	0	0	1
Ref.	3	1		0	0	0	0	0
Ref.	3	2		0	0	0	0	1
Ref.	3	3		0	0	0	0	0
3	2	1		0	0	0	0	1
3	2	2		0	0	0	0	1
3	2	3		0	0	0	0	0
3	1	1		0	0	0	0	0
3	1	2		0	0	0	0	0
3	1	3		0	0	0	0	1
3	3	1		0	0	0	0	0
2	1	1		0	0	0	0	2
2	1	2		0	0	0	0	3
2	1	3		0	0	0	0	0
2	2	1		0	0	0	0	0
2	2	2		0	1	0	1	2
2	2	3		1	0	0	0	6
2	3	1		0	0	0	0	1
2	3	2		0	0	0	0	0
2	3	3		0	0	0	0	0

			Class:	Insecta	Insecta	Insecta	Insecta	Insecta
			Order:	Diptera	Diptera	Diptera	Diptera	Diptera
			Suborder:					
			Family:	Chaoboridae	Simuliidae	Chironomidae	Chironomidae	Chironomidae
			Subfamily:					
			Tribe:			Chironomini	Chironomini	Chironomini
			Genus:			Polypedilum	Chironomus	Phaenospectra
Tolerance Value				**8**	**6**	**6**	**10**	**7**
Site	**Date**	**Rep.**						
CH2	1	1		10	5	1	0	0
CH2	1	2		23	0	2	0	0
CH2	1	3		5	0	0	0	0
CH2	2	1		1	0	0	6	0
CH2	2	2		0	0	0	7	0
CH2	2	3		0	0	0	1	0
CH2	3	1		0	0	0	0	0
CH2	3	2		0	0	0	0	0
CH2	3	3		0	0	0	0	0
CH3	1	1		11	0	0	0	0
CH3	1	2		0	0	0	0	0
CH3	1	3		2	0	0	0	0
CH3	2	1		0	0	0	0	0
CH3	2	2		4	0	0	5	0
CH3	2	3		0	0	0	1	0
CH3	3	1		0	0	0	0	0
CH3	3	2		0	0	0	0	0
CH3	3	3		0	0	0	0	0
Ref.	2	1		0	0	0	1	0
Ref.	2	2		0	0	0	14	0
Ref.	2	3		0	0	0	10	0
Ref.	3	1		0	0	5	0	0
Ref.	3	2		0	0	4	1	0
Ref.	3	3		0	0	6	0	0
3	2	1		1	0	0	0	0
3	2	2		0	0	0	0	1
3	2	3		0	0	0	0	0
3	1	1		9	0	0	0	0
3	1	2		0	0	0	0	0
3	1	3		1	0	0	0	1
3	3	1		0	0	0	0	0
2	1	1		1	0	0	0	0
2	1	2		4	0	0	0	0
2	1	3		0	0	0	0	0
2	2	1		1	0	0	11	0
2	2	2		1	0	0	45	0
2	2	3		0	0	0	8	0
2	3	1		0	0	2	0	0
2	3	2		0	0	3	0	0
2	3	3		0	0	2	0	0

			Class:	Insecta	Insecta	Insecta	Insecta	Insecta
			Order:	Diptera	Diptera	Diptera	Diptera	Diptera
			Suborder:					
			Family:	Chironomidae	Chironomidae	Chironomidae	Chironomidae	Chironomidae
			Subfamily:					
			Tribe:	Chironomini	Chironomini	Chironomini	Chironomini	Chironomini
			Genus:	Pseudochironomus	Paratendipes	Tanytarsus	Rheotanytarsus	Glyptotendipies
Tolerance Value				**5**	**6**	**6**	**6**	**10**
Site	**Date**	**Rep.**						
CH2	1	1		0	1	0	0	0
CH2	1	2		0	0	0	0	0
CH2	1	3		0	0	2	1	0
CH2	2	1		0	0	0	0	1
CH2	2	2		0	0	0	0	0
CH2	2	3		0	0	0	0	1
CH2	3	1		0	0	0	0	0
CH2	3	2		0	0	0	0	0
CH2	3	3		0	0	0	0	0
CH3	1	1		0	0	0	0	0
CH3	1	2		0	0	0	0	0
CH3	1	3		0	0	0	0	0
CH3	2	1		0	0	0	0	0
CH3	2	2		0	0	0	0	1
CH3	2	3		0	0	0	0	0
CH3	3	1		0	1	0	0	0
CH3	3	2		0	0	0	0	0
CH3	3	3		0	0	0	0	1
Ref.	2	1		0	0	0	0	0
Ref.	2	2		0	0	0	0	0
Ref.	2	3		0	0	0	0	0
Ref.	3	1		0	0	0	0	0
Ref.	3	2		0	0	0	0	1
Ref.	3	3		0	0	0	0	0
3	2	1		0	0	0	0	2
3	2	2		0	0	0	0	0
3	2	3		0	0	0	0	0
3	1	1		0	0	0	0	0
3	1	2		0	0	0	0	0
3	1	3		0	0	0	2	0
3	3	1		0	0	0	0	5
2	1	1		0	0	0	0	0
2	1	2		0	0	1	0	0
2	1	3		0	0	0	0	0
2	2	1		0	0	0	0	1
2	2	2		1	0	0	0	12
2	2	3		0	0	0	0	1
2	3	1		0	1	0	0	1
2	3	2		0	0	0	0	0
2	3	3		0	2	0	0	1

			Class:	Insecta	Insecta	Insecta	Insecta	Insecta
			Order:	Diptera	Diptera	Diptera	Diptera	Diptera
			Suborder:					
			Family:	Chironomidae	Chironomidae	Chironomidae	Chironomidae	Chironomidae
			Subfamily:					
			Tribe:	Chironomini	Chironomini	Chironomini	Chironomini	Tanypodinae
			Genus:	Endochironomus	Microtendipes	Cryptochironomus	Dicrotendipes	Thienemannimyia
Tolerance Value				**10**	**5**	**8**	**8**	**6**
Site	**Date**	**Rep.**						
CH2	1	1		1	0	1	0	0
CH2	1	2		3	0	1	0	0
CH2	1	3		2	0	0	0	1
CH2	2	1		5	0	0	1	1
CH2	2	2		0	3	0	1	2
CH2	2	3		0	3	1	2	0
CH2	3	1		0	0	0	0	0
CH2	3	2		0	0	0	0	0
CH2	3	3		0	0	0	0	0
CH3	1	1		0	0	2	0	0
CH3	1	2		0	0	0	0	0
CH3	1	3		0	0	0	0	0
CH3	2	1		1	2	0	0	0
CH3	2	2		2	1	0	0	1
CH3	2	3		0	4	0	0	0
CH3	3	1		0	0	4	1	1
CH3	3	2		0	0	0	0	0
CH3	3	3		0	1	1	0	1
Ref.	2	1		2	1	0	0	0
Ref.	2	2		1	0	0	0	1
Ref.	2	3		0	2	0	0	0
Ref.	3	1		0	0	0	0	0
Ref.	3	2		1	0	0	0	0
Ref.	3	3		0	0	0	0	0
3	2	1		3	0	0	1	0
3	2	2		4	1	0	0	0
3	2	3		0	0	0	0	0
3	1	1		0	0	0	0	0
3	1	2		0	0	0	0	0
3	1	3		0	0	1	0	0
3	3	1		5	0	0	1	9
2	1	1		0	0	1	0	0
2	1	2		0	0	1	0	0
2	1	3		0	0	0	0	0
2	2	1		2	0	0	0	0
2	2	2		21	0	0	4	2
2	2	3		2	1	0	0	1
2	3	1		0	0	1	0	0
2	3	2		0	0	0	0	2
2	3	3		0	0	1	0	0

			Class:	Insecta	Insecta	Insecta
			Order:	Diptera	Diptera	Diptera
			Suborder:			
			Family:	Chironomidae	Chironomidae	Chironomidae
			Subfamily:			
			Tribe:	Tanypodinae	Orthocladiinae	Orthocladiinae
			Genus:	Procladius	Nanocladius	Eukiefferiella
Tolerance Value				**9**	**7**	**4**
Site	**Date**	**Rep.**				
CH2	1	1		0	0	0
CH2	1	2		0	0	0
CH2	1	3		0	0	0
CH2	2	1		2	0	0
CH2	2	2		1	0	0
CH2	2	3		0	0	0
CH2	3	1		0	0	0
CH2	3	2		0	0	0
CH2	3	3		0	0	0
CH3	1	1		5	0	0
CH3	1	2		0	0	0
CH3	1	3		1	0	0
CH3	2	1		0	0	0
CH3	2	2		5	0	0
CH3	2	3		1	0	0
CH3	3	1		0	0	0
CH3	3	2		0	0	0
CH3	3	3		0	0	0
Ref.	2	1		1	0	0
Ref.	2	2		0	0	0
Ref.	2	3		2	0	0
Ref.	3	1		0	0	0
Ref.	3	2		1	0	0
Ref.	3	3		0	0	1
3	2	1		0	1	0
3	2	2		0	0	0
3	2	3		0	0	0
3	1	1		0	0	0
3	1	2		0	0	0
3	1	3		0	0	0
3	3	1		0	0	0
2	1	1		0	0	0
2	1	2		2	0	0
2	1	3		0	0	0
2	2	1		2	0	0
2	2	2		7	0	0
2	2	3		0	0	0
2	3	1		0	0	0
2	3	2		0	0	0
2	3	3		0	0	0

APPENDIX D
Abundance/Richness/Tolerance Index with Standard Error

Abundance

	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE	**Tolerance** Index	SE
Non-Remediated	867.7	139.2	90.7	31.8	105.5	33.5	281.2	47.9	5.4	0.5
Remediated	1082.3	397.2	124.9	44.3	136.0	49.1	496.7	248.0	5.9	0.5

Richness

	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE
Non-Remediated	6.3	0.9	1.1	0.3	1.3	0.3	2.8	0.4
Remediated	6.4	1.1	1.2	0.3	1.4	0.4	2.8	0.5

Abundance

Date	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE	**Tolerance** Index	SE
1	902.2	174.8	49.3	13.9	55.5	23.3	296.6	61.3	6.3	0.3
2	778.2	193.6	106.9	49.8	210.2	62.9	245.7	65.8	6.2	0.5
3	457.7	137.6	63.0	28.6	68.3	24.9	156.3	54.7	4.4	0.7

Richness

	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE
1	4.8	1.0	0.6	0.2	0.9	0.4	1.8	0.5
2	9.1	1.2	1.8	0.4	2.3	0.5	4.0	0.5
3	4.5	0.9	0.9	0.3	0.8	0.3	2.3	0.5

Abundance

	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE	**Tolerance** Index	SE
Non-Remediated	818.9	171.4	101.1	41.7	120.9	43.6	239.3	54.8	5.2	0.6
Remediated	1082.3	397.2	124.9	44.3	136.0	49.1	496.7	248.0	5.9	0.5
Reference	1013.8	225.9	59.2	24.8	59.2	24.8	407.0	85.3	6.1	0.3

Richness

	All taxa	SE	EPT	SE	ETO	SE	Chironomids	SE
Remediated	6.4	1.1	1.2	0.3	1.4	0.4	2.8	0.5
Non-Remediated	6.3	1.1	1.1	0.3	1.4	0.4	2.7	0.5
Reference	6.3	1.1	1.2	0.5	1.2	0.5	3.0	0.6