Diversity of Shenango River Fish at Sites with Varying Types of Land Use

By

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Abstract

Globally, fishes have the highest rate of discovery of new species and exist in greater numbers than all other vertebrates combined. However, over the course of only a few decades the amount of inland fishes in North America considered imperiled or extinct has increased 20-40%. The main threats contributing to the decline in diversity of North American fresh water fishes include destruction of habitat, water depletion, point and non-point source pollution, erosion and sedimentation, overexploitation, disease and parasitism, introduced species, and climate change (Walsh et al. 2009).

A modification of the Index of Biotic Integrity (IBI) was used to evaluate the fish diversity in the modified Shenango River system. An IBI is an index that evaluates and measures the health of a stream ecosystem based on multiple attributes of the resident fish assemblage. Each site was sampled and classified based on its deviation from the reference site and then classified as poor, fair, good or excellent. The IBI data was used to determine biological criteria, select sites for further studies, provide biological impact assessments, and assess status and trends of local freshwater fish assemblages. Species richness, Menhinick's index, species diversity and Shannon's index were determined for every site and sampling. All sites varied in IBI classification during different months. Site classifications were: no fish, poor, fair and good.

In addition to the IBI, additive partitioning was used to measure diversity. Additive partitioning is an operational method which allows the analysis of patterns of species diversity across multiple spatial scales and is usually expressed by the number of species or species richness. The total or gamma diversity found in a pooled set of communities sampled from the river at any scale can be partitioned into the average diversity occurring

within a sample (alpha diversity) and the average diversity among samples (beta diversity) (Pegg and Taylor, 2007). Alpha diversity was lower than beta diversity for all sites which was expected. Diversity and richness values and presence of disease and parasites suggest that while these sites are populated with fish communities there are possible connections to decreased diversity due to anthropogenic effects. However, seasonal variation in the physical characteristics of sites such as flow velocity and suspended sediment are also thought to contribute to low diversity and richness values at different times of the year.

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Chapter 1 Introduction and Literature Review

Although fresh water constitutes a mere 1% of the Earth's surface area and less than 0.01% of total water by volume, 43% or about 12,000 currently named fish species are found exclusively in fresh waters. There are approximately 1,200 currently recognized fish species found in the inland waters of North America (Walsh et al. 2009). Fishes found within the freshwater ecosystems of North America have at least 435 imperiled or threatened species, 72 species with populations declining, and 36 species that are now extinct from the wild (Walsh et al. 2009). Patterns of species richness for fresh water fishes are heavily influenced by anthropogenic factors as well as many environmental factors including competition, predation, habitat diversity, water chemistry, flow regimes, channel morphology and temperature (Oberdorff et al. 1995).

There are three major causes of fish mortality including natural causes, mechanical agents and polluting substances (Wood, 1960). Although the last 30 years have seen great advancements in protecting our freshwater from pollution and the cleanup of polluted waterways, pollution is still a major problem affecting the diversity and population size of fish species (Paller et al. 1983).

The majority of stream fish are not widely distributed. The abundance of local assemblages follows a log normal frequency distribution and therefore most species are few in number and restricted geographically (Sheldon 1988). Historically, records show significant declines of many stream fishes. One such fish, the rosy face shiner is currently widely distributed and common, yet by midcentury it had vanished from most of its range in Ohio (Sheldon 1988). Like most species rich fauna the majority of stream fish species can be considered rare and are therefore particularly susceptible to environmental stress or habitat fragmentation (Sheldon 1988).

Species-area relationships derived by Sheldon (1988) show that extinctions will follow the fragmentation of drainage networks. The greatest diversity of stream fishes is supported by streams of fourth order or higher. These large streams are susceptible to destruction of riparian zones, industrial and agricultural pollutants, channelization and impoundments which lead to the decline of diversity of stream fish assemblages and possible extinction of species (Sheldon 1988).

Urbanization can create many adverse effects on the species richness and fitness of stream fish assemblages and is second only to agriculture as an agent of stream degradation in the United States. After urbanization of catchment areas intermittent and perennial streams tend to show altered hydrologic regimes, elevation in nutrient and contaminant concentrations and degraded aquatic biota (Morgan and Cushman 2005). These conditions are typically very difficult to mediate or reverse. Many studies have reported that alterations in catchment land use have direct effects on stream fish populations. In six studies done by Morgan and Cushman (2001) fish diversity or indices of biotic integrity showed decreases at 10 to 12% imperviousness of the catchment (Morgan and Cushman 2005).

Fish assemblages found within smaller first to third order streams that receive groundwater input are particularly susceptible to the environmental impacts of urbanization (Morgan and Cushman 2005). These streams commonly have a natural low richness of fish species and are therefore very susceptible to loss of species and overall diversity due to alterations in hydrologic regimes and water quality caused by urbanization. These alterations have immediate effects on fish assemblages, including loss of breeding, decreased feeding and loss of resting habitat (Morgan and Cushman 2005).

Typically if a fish is exposed to a pollutant there are signs of illness or disease that can be found within the structure of the fish's gill. Due to the nature of the gill it is often one of the first visible areas of the fish affected by pollutants (Wilson and Laurent 2002). As a natural by-product of the decomposition of all nitrogen-containing organic matter, ammonia is a major constituent of secondary waste water. Although the impacts of ammonia concentrations discharged into aquatic systems by secondary treatment plants is uncertain, studies have shown that un-ionized ammonia is the most toxic form (Paller et al. 1983). The primary toxicant in most secondary wastewater effluents is residual chlorine, a product used for effluent disinfection. In addition, these studies suggest that residual chlorine is commonly the only contaminant found in secondary wastewater that has negative impacts on the distribution of fishes. Residual chlorine is a biocide and has been proven to be acutely toxic to fishes even at tenths of a ppm concentration (Paller et al. 1983).

One highly regarded concept on the ecology of larger and modified river systems offers support to the theory that diversity is regulated by a process which operates at larger, anthropogenic induced scales (Pegg and Taylor 2007). The Serial Discontinuity concept states that a river affected by anthropogenic sources will recover or reset downstream. Therefore, this concept supports the idea that dams utilized in the river can reset areas downstream to conditions similar to headwater streams. This in turn has dramatic effects on the aquatic biota of the river (Pegg and Taylor 2007).

Ecologists typically view the total species diversity found within a set of communities as the product of the average diversity found within a community (alpha) and the diversity between the communities (beta). This concept of species diversity takes the sum of alpha and beta diversities to give the total or gamma diversity. This additive partitioning of species diversity is very old, however ecologists are just now beginning to use this approach to examine patterns of species diversity (Veech et al. 2002).

Alpha and beta diversity are defined as within-habitat and between habitat diversity. According to the concept of additive partitioning, diversity can be partitioned across multiple spatial scales such that the total or gamma diversity on one spatial scale becomes within habitat diversity at the next higher scale. Therefore, the total diversity at one scale is determined by the alpha diversity and the between-habitat diversity at the next lower scale (Stendera and Johnson 2005).

There are important implications in the determination of scale influenced effects on the diversity of river fish, understanding the aquatic biota and determining goals for management and restoration. If the scale at which management efforts are implemented is disproportional to the scale at which they should be applied, mitigation efforts of anthropogenic influences on the river system will likely fail. For this reason a larger scale such as the watershed of the river should be taken into consideration for management of fish diversity. However, it is also important to address diversity at smaller spatial scales and alpha diversity or diversity within sites plays an important role on gamma diversity or overall diversity in modified river systems (Pegg and Taylor 2007). Smaller scale processes such as competition, predation and habitat availability have dramatic effects on fish communities at smaller scales which in turn affect the larger scale. It is important to manage the smaller scale microhabitats so that there is suitable environment for the single species while attempting to manage larger spatial anthropogenic modifications such as land use practices, management of the flow regime and maintenance of floodplain connectivity to protect fish diversity (Pegg and Taylor 2007).

A study done by Karr (1981) evaluated the anthropogenic effects on fish by attempting to refine a biotic assessment program for successful protection of freshwater fish resources. This assessment evaluates fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic environment. The biotic assessment program that he created is the index of biotic integrity or IBI. Use of this assessment involves the assumption that a fish sample at any given site represents the entire fish community (Karr 1981).

Although multiple groups of organisms have been used as indicators of environmental quality, there is still debate among biologists if there is a single group that can act as an indicator. Under ideal circumstances, a biological monitoring program should be based on an integrative approach of sampling and analyzing several major taxa. However, limited funds, expertise and time for assessment argue for a less complex approach (Karr 1981).

Although taxa such as benthic macro-invertebrates have commonly been used in assessments of water quality there are fundamental problems with this approach. One problem is that they require specialized taxonomic expertise. Invertebrates are difficult and tedious to work with and identify. In addition information is often lacking on the life history of the organisms and the results are difficult to translate into values that are not confusing to the general public (Karr 1981).

However, fish have multiple advantages as indicators of water quality and the status of the aquatic ecosystem. The life history information is extensive for most fish species and fish communities typically display an array of species that represent several trophic levels including omnivores, herbivores, insectivores, planktivores, and piscivores. In addition, their position at the top of the aquatic food web allows for analysis of the structure and function of the watershed environment. Fish are also readily identifiable and working with them requires relatively little training. Another advantage is that most samples can be measured, examined and identified at the field site, with release of study organisms after sampling. Fish are usually present, even in the smallest streams and in all but the most polluted waters increasing the success rate of sampling (Karr 1981).

The absence or presence of pollution intolerant species is an important criterion in determining fish diversity and IBI classification. There are several easily identifiable species that are the first to decline in each portion of the river due to anthropogenic factors. Examples of the pollution sensitive species include the blacknose shiner (*Notropis heterotepis*), Northern Hogsucker (*Hypentelium nigricans*), silver redhorse (*Moxostoma anisurum*), longear sunfish (*Lepomis megalotis*), banded darter (*Etheostoma zonale*), and mottled sculpin (*Cottus bairdi*) (Karr 1981).

The classification of sites using the IBI follows a structure of ranking from excellent to very poor. Excellent sites are in the best possible condition without influence of man. All locally expected species for the habitat and stream size, including the most pollution intolerant species are well represented and existing in a balanced trophic structure. Good sites display species richness somewhat below expected levels especially due to loss of many pollution intolerant species. As well as some species with less than optimal abundances or size distribution. In addition, the trophic structure shows some signs of stress. Fair sites display signs of further deterioration including fewer pollution intolerant forms. The trophic structure shows signs of being skewed and older age classes of top predators may be rare or not present. Poor sites are dominated by omnivores, pollution-tolerant forms, and habitat generalists. There are few to no top predators and growth rates and condition factors are typically depressed. In poor sites diseased fish are often present. Very poor sites have few fish present, mainly introduced or very tolerant forms. Fish displaying disease, parasites, fin damage, and other abnormalities are common in very poor sites. Finally, sites that have no species sampled are categorized as “no fish” sites (Karr 1981). These factors were accounted for in the IBI classification for this study.

Studies done by Karr (1981) using the IBI found that samples with fewer than 20% of individuals as omnivores to be good, while those with over 45% omnivores to be badly degraded. Another important aspect to the dynamics of the fish community is the proportion of the community that is insectivores. Typically, a strong inverse correlation is found between abundance of insectivores and omnivores. Presence of top predators such as bass is another important indicator. Stable populations of top predator species indicate a relatively healthy, diverse community with multiple functioning trophic levels. As the quality of the stream declines, these functional feeding groups disappear.

Oberdorff (1992) modified the IBI to characterize rivers in France based on fish assemblages. The IBI was chosen because it measures the health of fish assemblages as well as catchment and stream quality and reflects human influence on environmental structures and processes. While they retained the original metrics of the IBI they modified it to a different fish fauna on a different continent. The study successfully used the modified IBI to evaluate fish diversity in the rivers in France (Oberdorff 1992).

Additional criterion can be useful in classifying diversity and health of a site such as the frequency of fish with tumors, fin damage or deformities, parasites, and other indicators of disease or anomalies. In headwater streams, the frequency of fish and number of parasites per fish with the black spots of a trematode parasite (*Neascus spp.*) seems to increase dramatically in modified watersheds (Karr 1981). These factors were weighted heavily in the IBI classification of each site.

Use of this assessment involves the assumption that a fish sample at any given site represents the entire fish community. It would be biased to sample only the large species or the species of sport and commercial relevance. Only fry or young-of-the-year that are too small to sample with mesh seines can be excluded. These fish are typically excluded from samples because of difficulties involved in sampling and identification. Variation in stream composition requires variation of sampling techniques. Seine nets seem to be the best sample tool for smaller first to fifth order streams (Karr 1981). However, seine nets are rarely able to catch larger fish species. Another disadvantage of seine nets is that benthic species such as darters and suckers often hide under the shelter of substrate and do not emerge at some times unless disturbed. Even when benthic species are disturbed toward the nets they often are able to slip underneath. While electro fishing stuns all the fish in a given area, benthic species that do not have a swim bladder do not float to the top and are therefore not sampled. For this reason both sampling methods, net sampling and electro-fishing, are suggested for completed evaluation of diversity from a river system.

In his 2006 study John Lyons used a modification of the IBI to assess fish diversity in streams in Wisconsin. Lyons included seven of the original twelve metrics in his assessment. Despite the inherent challenges of seasonal variation found within sites Lyons found it was possible to develop an accurate and reasonably precise fish-based IBI for Wisconsin intermittent headwater streams. He found that the IBI accurately reflected the environmental quality of the test data subset and temporal variation in IBI scores at individual stations showed no clear patterns in relation to season, year, or human impact (Lyons 2006).

There are multiple parameters to consider when assessing the diversity of fish communities. Species composition and species richness which is a measure of the number of species found in a sample can be determined by number of species, presence of intolerant species, and species richness and composition of darters, suckers, and sunfish. Ecological factors include number of individual per sample, proportion of omnivores, proportion of insectivores, proportion of top predators and proportion with tumors, disease, fin damage and other anomalies (Karr 1981).

Shenango River and Watershed

The Shenango River is a modified river system that is approximately 110 kilometers long and drains a watershed that is 2,623 square kilometers. Located in west central Crawford County, Pennsylvania it flows northwest through Pymatuning Swamp to Pymatuning Reservoir, on the Pennsylvania/Ohio border (Columbia Gazetteer, 2010).

Within the Shenango watershed there are more than 131,000 acres of cropland and 93,740 acres of cultivated crops (Table: 1.0). It is located in northwestern Pennsylvania in Crawford, Mercer and Lawrence counties. The elevation ranges from 1,555 feet to 738 feet above sea level at the lowest point. The largest land use in the Shenango River Watershed is deciduous forest (38%). The northern edge of the Shenango River Watershed is connected to the Pymatunning Watershed. These waters eventually run into the Shenango River and to the sampling location of this study. The average precipitation for this area is 36-44 inches annually (USDA, 1993).

Table: 1.0 Land use of the Shenango Watershed in Crawford County (USDA, 1993).

Land Use	Acres	Percent
Water	22,311	4.4
Developed Open Space	44,193	8.8
Developed, Low Intensity	20,470	4.1
Developed, Medium Intensity	4,511	0.9
Developed, High Intensity	1,742	0.3
Deciduous Forest	191,175	38.1
Evergreen Forest	3,632	0.7
Mixed Forest	972	0.2
Pasture/Hay	97,314	19.4
Cultivated Crops	93,740	18.7
Woody Wetlands	11.043	2.2
Shrub/Scrub	3,095	0.6
Grassland/Herbacious	7,304	1.5

Water quality problems cited included seasonal flooding and sedimentation from sand and gravel mines. Poor water quality was often cited as a problem in Paden Creek. Other problems included location of feedlot areas close to streams, poor runoff controls on land where manure was spread daily and poor conservation plans (Crawford County Conservation District 2007).

There is concern that pollutants are affecting the watershed including nutrients, metals, chlorine, PCBs, pathogens, and sediment. Other sources of water quality degradation include channelizing and altering stream beds, clearing vegetation, failing septic systems and development or agriculture without best management practices (Trumbull Soil and Water Conservation District.Web).

Objective

The objective of the research is to investigate the diversity of fish communities in the Shenango River at different land use points. The land use point will correspond to different human based activities. The expectation is that activities, such as industrial uses, will put additional stress on fish community structure and lower water quality resulting in reduced fish diversity. Additive partitioning was calculated for each site. Alpha, beta and gamma diversities are used to reflect the diversity of each site in comparison to the reference site. In order to determine the degree to which surrounding land use effects fish community structure, and to evaluate the diversity of fish assemblages the IBI was modified and used to determine a classification for each sampling site (Karr 1981).

Chapter 2 Materials and Methods

Field Site Descriptions

The five sampling locations included in this study were positioned downstream the Shanango River Lake. All sampling sites were located south or downstream of the Shenango River Tailwater dam near Shapesville, PA and all are within the Shenango River watershed (Figure 2.0, Table 2.1).

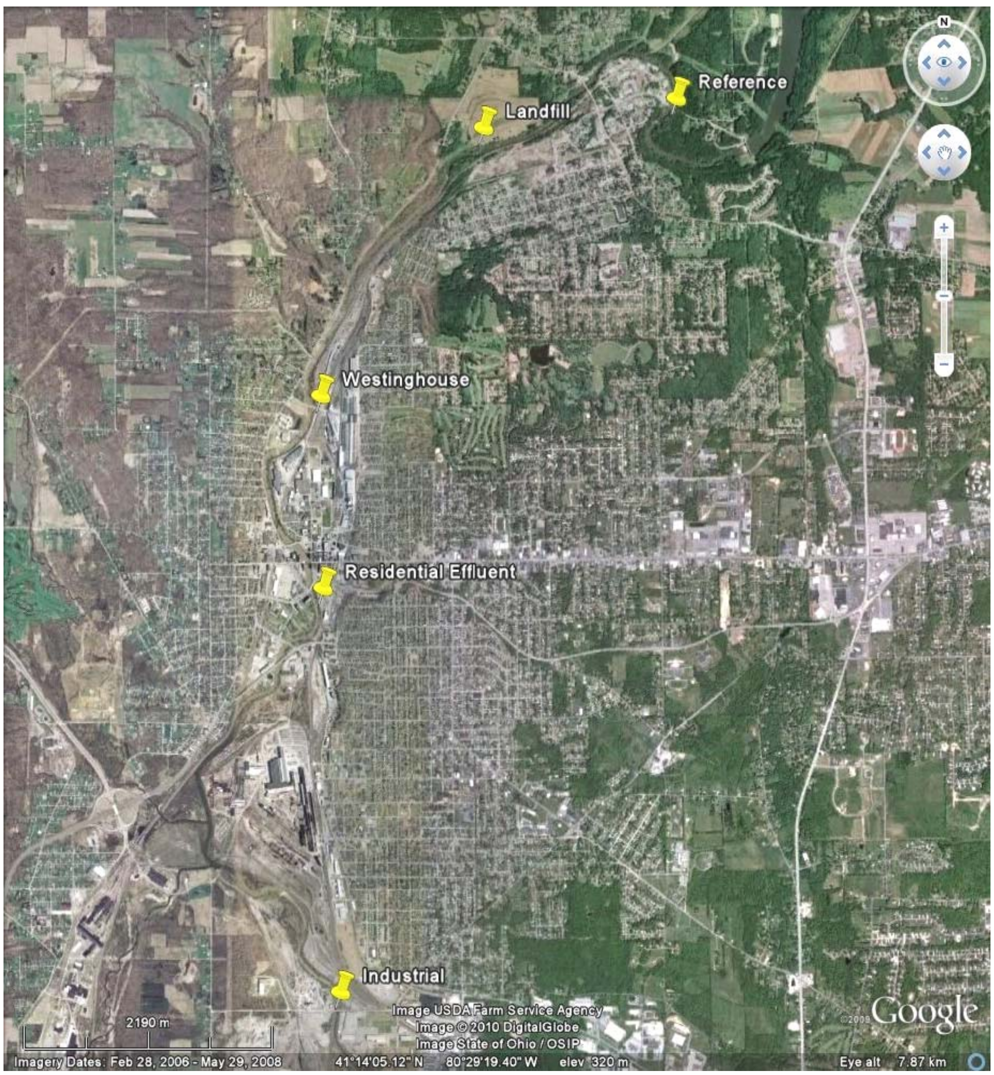

Figure: 2.0 The five sampling sites located along the Shenango River, PA (Google maps).

Table: 2.1 Latitude, Longitude and Elevation of Sampling sites along the Shenango River, PA.

Site	Latitude (N)	Longitude (W)	Elevation (m)
Reference	41° 16' 01.27"	80° 28' 13.58"	263
Landfill	41° 15' 51.75"	80° 29' 27.50"	261
Westinghouse	41° 14' 40.37"	80° 30' 30.10"	258
Residential Effluent	41° 13' 46.05"	80° 30' 28.54"	256
Industrial	41° 11' 56.18"	80° 30' 20.20"	251

Reference site

The reference site was surrounded by low impact mixed woodland forest and was a common fishing area for locals. It was chosen because of its limited surrounding land use and was expected to display an acceptable representation of the local fish assemblages (Figure 2.1). This site is 45% shaded especially near the banks. This section of the river is wider than any of the other sites. There is no shading in the middle of the river where flow velocity is highest. While both 8' and 20' seine nets were used at this site, the twenty foot net produced better results. Sampling was done along a sand bar where flow velocity is low and the water depth ranges from several inches to roughly four feet. Additional sampling was done in riffles further away from the sand bar where the water depth is much lower (6-24"). Both sweep seining and kick seining were used at this site. The substrate of this site is comprised mostly of small to medium sized rocks and also silt and sand.

Figure: 2.1 Image of the reference site in the Shenango River, PA with approximate sampling location identified by a white arrow. (Google maps).

Landfill Site

The landfill site is located adjacent to the River Run Landfill. This landfill is a 102-acre inactive landfill that operated from 1962 until 1986. The landfill accepted municipal and industrial wastes, including metal processing waste, polychlorinated biphenyl (PCB) wastes, and asbestos. In 1987 the landfill was approved for closure. A cap was put over the area to keep rainwater and runoff from spreading contaminants. In addition a leachate collection system and a ground water dam were installed. The landfill site was removed from the National Priorities List of most hazardous waste sites in January 2004 (U.S. EPA 2010). The site was selected to determine if there are any noticeable impacts on fish diversity caused by its presence (Figure 2.2). The area sampled has characteristics of a wetland or swamp. The area sampled was partially enclosed shallow, pooled water with emergent vegetation. Since this area is isolated from the main channel of the river it has little to no flow and therefore makes an ideal habitat for young fry and fingerlings of a non-benthic nature to grow. The isolation from the active channel of the river might essentially make this site a nursery for young fish to feed and grow in the absence of many predators that they would otherwise be in contact with (Oberdorff et al. 1995). While both the eight and twenty foot seine nets were used at this site the eight foot net was more successful. Sampling was done along a gravel bar and along a somewhat steep bank that separates this site from the main portion of the river. Sampling efforts at this site only required sweep seining. The substrate of this site consists almost entirely of sand and silt. This site is approximately 80% shaded in the portion where sampling was done.

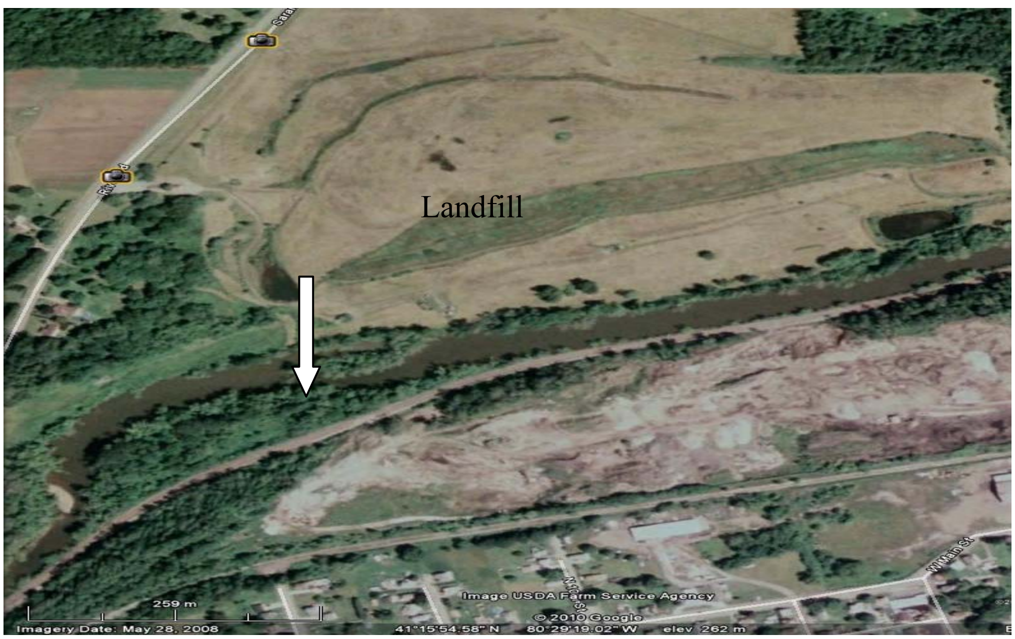

Figure: 2.2 Image of the landfill site on the Shenango River, PA with approximate sampling location identified by a white arrow. (Google maps).

Westinghouse Site

The Westinghouse site is the location of the former Westinghouse Electric Sharon Transformer Plant. It is a 58-acre facility that operated from 1922 to 1985. Between 1936 and 1976, Westinghouse used blends of polychlorinated biphenyls (PCBs) and trichlorobenzene in the manufacturing of some of the transformers. Soil clean-up activities began in October of 2001 with river sediment and riparian zone removal starting in July 2004. All clean-up activities have been completed by September 2006 (U.S. EPA 2010). Figure 2.3 shows the Westinghouse site at the time of sediment removal and remediation. The site commonly contained a fair amount of brown algae and dead fish could usually be seen lying in the shallow rocky waters around the site. Both seine nets were employed at this site. However the twenty foot seine net typically produced better results. The site was approximately 40% shaded with one portion of the site in the shade and the other completely un-shaded. The substrate of this site was a mix of sand, silt, gravel and larger rocks. When the sediment removal was achieved, a large amount of rip-rap was used as fill; sampling was done along this rocky bank. Sampling efforts at this site only required sweep seining. Additional sampling was done along a sand bar underneath the Clark Street bridge.

Figure: 2.3 Image of the Westinghouse site on the Shenango River, PA with approximate sampling location identified by a white arrow. (Google maps).

Residential Effluent Site

This site was chosen because it is located in downtown Sharon and was expected to have signs of impact from surrounding residential land use (Figure 2.4). There is a large culvert directly upstream of the sampling site which channels storm water runoff from a residential community on the eastern side of the river. Most of the areas where seining was possible were fast moving riffles. Typically benthic species are found in fast moving riffles which can swim under the seining net easily. Use of the twenty foot seine net for this site was highly impractical. Therefore the eight foot seine net was used exclusively. Both sweep seining and kick seining were used at this site. This site was approximately 45% shaded with shading found only near the banks of the River. Sampling was done along a gravel bar in shallow fast moving water. The substrate of this site includes sand, silt and many rocks of varying size.

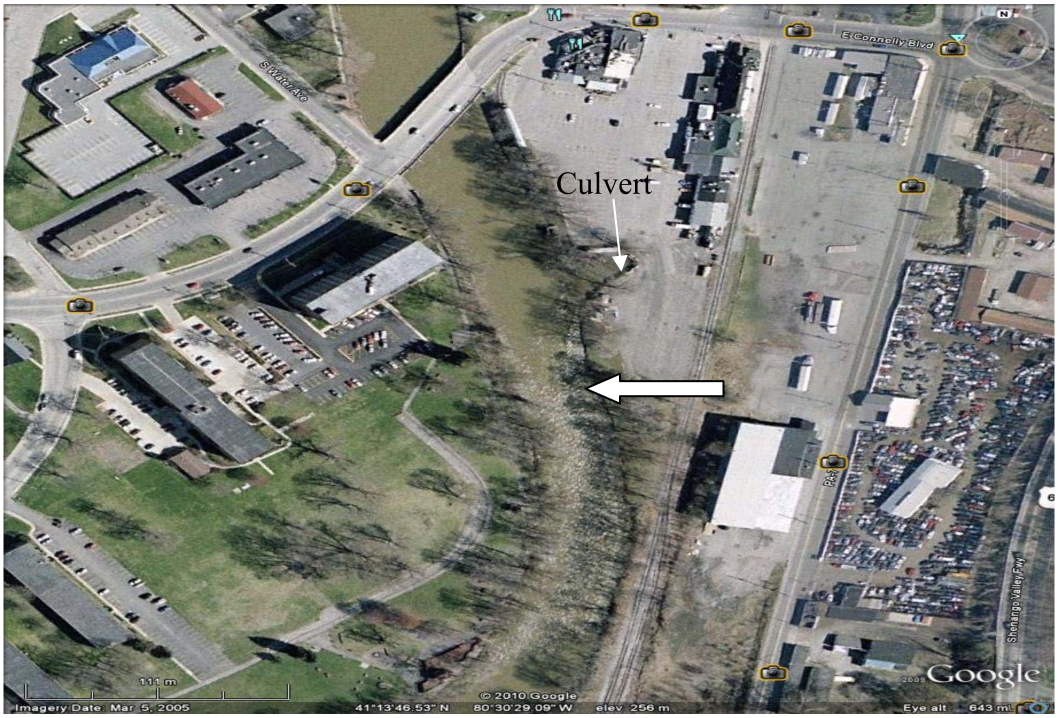

Figure: 2.4 Image of the residential effluent site on the Shenango River, PA with approximate sampling location identified by a white arrow. (Google maps).

Industrial Site

This site was selected for its close proximity to areas of industrial use specifically the steel industry in the area. The steel industry makes up about 400 acres of land within this section of the watershed (U.S. EPA 2010). Beginning about 1900, the steel industry used the area to dispose of furnace slag and sludge. From 1949 to 1981, millions of gallons of spent pickle liquor acid were dumped believing that it would evaporate and the remaining acid would be neutralized by the carbonate in the slag (U.S. EPA 2010). This site was suspected to display signs of impact on the structure and diversity of fish assemblages due to the degree of industrial land use around the site (Figure 2.5). The vast majority of surrounding land has been denuded of vegetation except for a small line of trees and weeds that runs along the river. This site was ideal for using a twenty foot seine net which maximized the number and species of fish caught. The industrial site had a large pool next to a gravel bar which was out of the active channel of the river where flow velocity was high. This area is where the majority of seining was done. This site had only 30-35% shading and shade was found only along the banks. The substrate consisted mainly of sand and silt with some small rocks. It was discovered that this site was home to a large population of pumpkinseed and blue gill sunfish. On the last sampling date, July 6th, multiple nests were observed on the bottom of the river bed in the above mentioned pool. The male sunfish make circular nests on the river bed consisting of small to medium sized stones. They clean and guard the nests hoping that a female will choose to lay her eggs there (Wallace 1980).

Figure: 2.5 Image of the industrial site on the Shanango River, PA with approximate sampling location identified by a white arrow. (Google maps).

Sampling Methods

This project is intended to determine the diversity of fishes found within the Shenango River at five locations, each corresponding with a different land use. The sites include a reference site, landfill site, Westinghouse site, residential effluent site, and industrial site.

Figure 2.6: Sampling the reference site along the southern portion of the Shenango River.

For this study, sampling methods included both sweep seining and kick seining. Sampling efforts were varied when water levels were low and flow velocity was high. The goal of every sampling effort is to obtain a representative sample of the entire fish community in the sample area. Sampling was done with an 8 and 20 foot seine net. Each sampling site was swept with the nets 6-12 times (Figure 2.6). Most areas were accessed from the shoreline except the landfill site for which a rowboat was needed to access the site. A fish board was used to measure each fish in centimeters and occurrences of fish diseases were noted. A field guide to freshwater fishes (Page and Burr 1991) was used to identify fish to species.

Four of the five sites were sampled three times, once each in July, August and September of 2009. However, the Westinghouse site was added after the initial sampling had begun and was therefore only sampled twice in 2009. All sites were sampled an additional three times in June and July of 2010.

Fishes sampled were identified, measured and visually inspected for signs of illness or disease which could be associated with surrounding land use. In addition, on site water quality parameters (temperature, dissolved oxygen, specific conductivity and pH) were measured. This allows us to evaluate the diversity of fishes found in the Shenango River, any visible disease or illness and to speculate on the degree to which surrounding land use effects fish diversity and overall health.

The effects of urbanization and habitat fragmentation were evaluated by comparing species caught to species known to be native in the past and present. Sampling data was provided by The Pennsylvania Fish and Boat Commission for the site which most closely corresponded to the sample sites for this study. The IBI or Index of Biotic Integrity was used to evaluate and measure the health of the river ecosystem based on multiple attributes of the resident fish assemblage.

Analysis

Diversity and Richness Indices

Species richness is a measure of the number of species found in a sample. Average species richness and overall species richness were observed for each site. Species richness was determined for each sampling date. Because the larger the sample the more species one would expect to find, an index can be used to represent richness. This measure of species richness (D) is known as the Menhinick's index which attempts to correct for sample size between sites using equation (1).

$$D = s \div \sqrt{N} \qquad \text{(Eq. 1)}$$

Where *s* equals the number of different species found in the sample, and *N* equals the total number of individual organisms in your sample. Menhinick's index was calculated for each sampling date for every site. Menhinick’s number approaches zero when there are a high number of individuals (Calculating Biodiversity. Web).

Species diversity differs from species richness in that it takes into account both the numbers of species present and the dominance or evenness of species in relation to one another. The Shannon index (H) is a measure of species diversity and is calculated using equation (2)

$$H = \sum (p_l) \, |\ln p_l| \qquad \text{(Eq. 2)}$$

Where (pl) is the proportion of the total number of individuals in the population that are in species l. The Shannon diversity index was calculated for each sampling date for every site. A Shannon index of 1.5 indicates low diversity where as a Shannon index of 3.5 indicates high diversity (Stendera and Johnson 2005).

Index of Biotic Integrity

It was not practical or necessary to employ all of the original twelve metrics found in the IBI. However, six of the metrics were utilized to assign each sample IBI classification and three metrics were taken into consideration. The three metrics not included were not used because they were not as relevant to this study. The three metrics that evaluate trophic structure were taken into consideration but not used as a major indicator of the species diversity of every site due to seasonal variation in characteristics of water quality that may have factored into the lower species richness and diversity values throughout the two year study. This seasonal variation could be the main reason that incomplete and complete trophic structures were observed within the same site at different times. In addition historical records of trophic structure for the Shenango River are lacking. Proportion of green sunfish was not included because we did not catch any green sunfish at any sites. Proportion of darter species was excluded because of a sampling bias that is inherent with the use of seine nets. Benthic species such as darters can easily evade the nets by swimming under them through the substrate. Proportion of hybrid species was not selected because we had no hybrid species that were identifiable. The metrics chosen include number of species, number of sucker species, number of sunfish species, number of intolerant species, number of individuals in the sample and proportion of individuals with disease. In addition, three metrics of trophic structure were taken into consideration. Although presence of sunfish species is an indicator of a healthier fish community, sunfish that were sampled consistently had red tumors and therefore are seemingly subject to disease caused by water quality degradation (Karr 1981).

According to Karr use of the IBI involves the assumption that a fish sample at any given site represents the entire fish community. Using this concept and the six chosen IBI metrics as a framework each sampling site has been classified as either no fish, poor, fair or good in Table 3. There are several species listed by Karr which are intolerant of pollution. Of the listed species there were two species that were caught in this study, the northern hogsucker and the banded darter. Since these species are known to be intolerant to poor water quality their presence or absence at a site was weighted heavily in the IBI classification. The number of species, proportion of individuals and proportion of individuals with disease are crucial in the determination of species diversity and were also weighted heavily in the determination of IBI classification for this study. The numbers sucker was weighted with slightly less relevance because only one sucker, aside from the pollution intolerant hogsucker, was sampled in the entire study. While sunfish were sampled at multiple sites they often were the species with symptoms of disease. Therefore their presence suggests higher diversity yet they are subject to disease which could be due to degradation of water quality.

Additive Partitioning

Additive partitioning was also used to analyze patterns of species diversity across multiple scales. With additive partitioning, any measure of diversity can be partitioned into its component parts; alpha diversity and beta diversity. Gamma diversity is the sum of the component parts. Each component is calculated on a spatial scale. Alpha diversity includes diversity within a site and is represented by the Shannon diversity index. The average of the Shannon index was calculated for all sampling dates for each site. This average is the alpha diversity of each site and is compared to the reference site. Alpha diversity therefore evaluates regional variation and does not take into account temporal variation among a given site. Beta diversity includes diversity between the reference site and each impacted site (Pegg and Taylor 2007, Stendera and Johnson 2005). Beta diversity was calculated by determining the total number of species common to each site and unique to each sampling location (Eq. 3).

$$\beta = (S_1 - c) + (S_2 - c) \qquad \text{(Eq. 3)}$$

Where S_1 is the total number of species in community 1 and S_2 is the total number of species from community 2 and c is the number of species that is common to both communities. In this study, S_1 will represent the reference location and S_2 is all the impacted sampling sites. Gamma diversity is then determined by the summation of alpha and beta diversity values.

The vast majority of large river systems can be organized spatially as a hierarchy based on ecological differences in the geomorphology and hydrology of the river. Once these differences were determined additive partitioning was used to evaluate multiscale patterns of species diversity by simultaneously examining the role of each level to the total diversity of the river. Partitioning spatially explicit diversity can assist in determining whether site locations or larger scales are providing the greatest contribution to species diversity (Pegg and Taylor 2007).

Chapter 3 Results and Discussion

Overall twenty fish species and 725 fish have been sampled from the five locations over a two year period (Appendix, Table: 32A). Species richness varied greatly from site to site and during different times of the year. The site with the highest species richness sampled was the landfill site. Although the landfill site yielded eleven different species in July of 2009 it yielded only three species on two separate occasions. To account for this variation an average of species richness was calculated for all samples from the sites over two years study. The reference site displayed the second highest average species richness (Table: 3.0).

Table: 3.0: Average Species Richness, Overall Species Richness and Average Menhinick's index.

Site	Average species richness± *sd*	Overall species richness	Average Menhinick's index *(D)* ±*sd*
Reference	4.7 ± *1.75*	13	1.*15* ± *0.6*
Landfill	5.2 ± *2.87*	13	1.05 ± *0.52*
Westinghouse	3.8 ± *2.07*	11	0.77 ± *0.48*
Residential Effluent	2.8 ± *0.75*	8	0.70 ± *0.17*
Industrial	4.6 ± *0.75*	11	1.03 ± *0.23*

sd = standard deviation

Even though the average of species richness indicates that the landfill site had higher average species richness than the reference site, the reference site had the highest Menhinick's index (Table: 3.1). This indicates that the number of fish caught during each sampling is influencing the average species richness. The industrial site had the next highest average species richness and was nearly as varied in species as the reference site. The Westinghouse site had considerably lower average species richness which is consistent with the state of the site. Finally the residential effluent site showed the lowest species richness as well as the lowest Menhinick's index.

Table: 3.1 Species Richness (Number of Species), Overall Species Richness and Menhenick's index of species richness for each sampling location.

Site	Sample Date	Species Richness (Number of Species)	Overall Species Richness	Menhenick's index *(D)*
Reference	7/14/2009	8	13	1.95
Reference	8/11/2009	4		0.75
Reference	9/25/2009	5		0.78
Reference	6/2/2010	4		1.26
Reference	6/22/2010	3		1.73
Reference	7/6/2010	4		0.41
Landfill	7/14/2009	10	13	2.04
Landfill	8/11/2009	3		0.71
Landfill	9/25/2009	3		0.95
Landfill	6/2/2010	3		0.53
Landfill	6/22/2010	6		0.92
Landfill	7/6/2010	3		1.13
Westinghouse	8/11/2009	5	11	0.8
Westinghouse	9/25/2009	5		1.08
Westinghouse	6/2/2010	3		0.7
Westinghouse	6/22/2010	4		1.26
Westinghouse	7/6/2010	0		0
Residential effluent	7/14/2009	2	8	0.49
Residential effluent	8/10/2009	4		0.59
Residential effluent	9/25/2009	3		0.87
Residential effluent	6/2/2010	3		0.9
Residential effluent	6/22/2010	2		0.57
Residential effluent	7/6/2010	3		0.75
Industrial	7/17/2009	5	11	1.35
Industrial	8/10/2009	5		0.78
Industrial	9/25/2009	6		1.15
Industrial	6/2/2010	4		1.2
Industrial	6/22/2010	5		0.92
Industrial	7/6/2010	4		0.78

The reference site, the landfill and the Westinghouse sites seemed to have more seasonal fluctuations of fish species as notes by the higher standard deviations (Table: 3.2). These sites seem to be more influenced by seasonal changes. On July 22, 2010, the reference site was recorded as having large amounts of algae, especially in the shallow waters, furthermore, this date had the lowest species richness for that site.

Table 3.2: Shannon Diversity Index, Average Shannon diversity and standard deviation.

Site	Sample Date	Shannon Diversity (H)	Average Shannon Diversity	Standard Deviation
Reference	7/14/2009	1.905	1.226	0.791
Reference	8/11/2009	2.234		
Reference	9/25/2009	1.233		
Reference	6/2/2010	1.314		
Reference	6/22/2010	0.17		
Reference	7/6/2010	0.497		
Landfill	7/14/2009	1.631	0.9950	0.373
Landfill	8/11/2009	0.588		
Landfill	9/25/2009	1.204		
Landfill	6/2/2010	0.806		
Landfill	6/22/2010	0.785		
Landfill	7/6/2010	0.956		
Westinghouse	8/11/2009	0.473	0.5300	0.538
Westinghouse	9/25/2009	1.431		
Westinghouse	6/2/2010	0.448		
Westinghouse	6/22/2010	0.298		
Westinghouse	7/6/2010	0		
Residential effluent	7/14/2009	0.455	1.0653	1.377
Residential effluent	8/10/2009	3.807		
Residential effluent	9/25/2009	1.099		
Residential effluent	6/2/2010	0.324		
Residential effluent	6/22/2010	0.456		
Residential effluent	7/6/2010	0.251		
Industrial	7/17/2009	1.48	0.8152	0.408
Industrial	8/10/2009	0.878		
Industrial	9/25/2009	0.993		
Industrial	6/2/2010	0.338		
Industrial	6/22/2010	0.732		
Industrial	7/6/2010	0.47		

The reference site displays the highest Shannon Diversity index followed by the residential effluent site (Table 3.2). However, data from August 10, 2009 included a large school of emerald shiners which raised the diversity index to an unusually high value. This data point could be an outlier which skewed the average diversity index to double what it would be if the data point was not included. The diversity values then followed the order of landfill > industrial > Westinghouse. All sites showed diversity indices less than 1.5 indicating low diversity for all sites. The index values could increase if multiple sampling methods were used.

The Industrial site yielded sunfish on every sampling date as well as a diversity of several other fish including largemouth bass which represent piscivorous predators in the fish assemblage. However, these fish assemblages are seemingly susceptible to their degraded environment resulting in tumors. This disease suggests that there are impacts to fish assemblages that are caused by surrounding land use or legacy contaminants.

Although there is a large breeding population of sunfish at the industrial site, multiple sunfish displayed small red masses. This is an indication that there may be pollutants affecting the fish health and causing the fish to have this disease. Several sunfish that were caught from the industrial site and the Westinghouse site had small red bumps that are likely to be orocutaneous papillomas which consist of broad based, well demarcated papillomatous masses protruding from the mucosal or cutaneous surface. A number of viral agents and chemical contaminants may serve as initiators or promoters of the tumors (Poulet et al. 1994). These masses are referred to as neoplasms and are tumors caused predominantly by epidermal papillomas (Figure 3.1). Papillomas consist of folded growths of the epidermis which are supported and nourished by branching connective tissue known as the stroma. Unlike a polyp, pampilloma displays strong hyperplastic thickening of the epithelium. This significantly increases the number of undifferentiated epidermal cells, while highly differentiated cells are reduced in size and number. Nodular swelling will often occur as well as a flat thickening of the skin in addition to the papillomas (Peters and Waterman, 1979). In addition, many of the fish that were sampled had large amounts of the trematode parasite (*Neascus spp*.) which is an indicator of a modified watershed (Figure 3.2). These could be signs of impacts of surrounding land use on the health and diversity of local fish species. All species sampled that had either *trematode* parasites or orocutaneous papillomas are recorded in Table: 3.3. Although on-site water quality parameters did not indicate degraded water quality, other contaminants may be the cause of these heath effects (Table: 3.4) (Karr 1981). Further chemical analysis would be needed along with toxicity testing to determine if the disease occurrence was due to current inputs or from legacy contaminants or other factors.

Figure 3.1: Photo of the tumors found on pumpkinseed sunfish in the Shenango River.

Figure 3.2: Photo of trematode parasite found on many fish in the Shenango River.

Table: 3.3 All species sampled with *trematode* parasite or orocutaneous paillomas.

Site	Date	Species	***Trematode* Parasite**	**orocutaneous papillomas**
Reference	7/14/2009	Johnny darter	✓	
Reference	9/25/2009	largemouth bass	✓	
Reference	9/25/2009	largemouth bass	✓	
Reference	9/25/2009	largemouth bass	✓	
Reference	8/10/2009	largemouth bass	✓	
Reference	8/10/2009	spot tail shiner	✓	
Reference	6/2/2010	greenside darter	✓	
Reference	6/2/2010	greenside darter	✓	
Reference	6/2/2010	banded darter	✓	
Reference	6/22/2010	greenside darter	✓	
Landfill	8/11/2009	largemouth bass	✓	
Landfill	8/11/2009	largemouth bass	✓	
Landfill	8/11/2009	largemouth bass	✓	
Landfill	8/11/2009	largemouth bass	✓	
Landfill	8/11/2009	largemouth bass	✓	
Landfill	6/22/2010	yellow perch	✓	
Westinghouse	8/11/2009	white sucker		✓
Westinghouse	8/11/2009	smallmouth bass	✓	
Westinghouse	9/25/2009	largemouth bass	✓	
Westinghouse	9/25/2009	largemouth bass	✓	
Westinghouse	9/25/2009	largemouth bass	✓	
Westinghouse	9/25/2009	largemouth bass	✓	

Westinghouse	9/25/2009	largemouth bass	✓	
Westinghouse	9/25/2009	smallmouth bass	✓	

Table:3.3 Continued

Site	Date	Species	*Trematode* Parasite	orocutaneous papillomas
Westinghouse	9/25/2009	smallmouth bass	✓	
Westinghouse	9/25/2009	smallmouth bass	✓	
Westinghouse	9/25/2009	smallmouth bass	✓	
Westinghouse	9/25/2009	smallmouth bass	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	emerald shiner	✓	
Westinghouse	9/25/2009	pumpkinseed sunfish		✓
Westinghouse	6/22/2010	pumpkinseed sunfish		✓
Industrial	6/2/2010	largemouth bass	✓	
Industrial	7/17/2009	pumpkinseed sunfish		✓
Industrial	7/17/2009	pumpkinseed sunfish		✓
Industrial	7/17/2009	pumpkinseed sunfish		✓
Industrial	7/17/2009	logperch darter	✓	
Industrial	8/10/2009	pumpkinseed sunfish		✓
Industrial	8/10/2009	emerald shiner		✓
Industrial	6/22/2010	pumpkinseed sunfish		✓
Industrial	7/6/2010	pumpkinseed sunfish		✓
Industrial	7/6/2010	pumpkinseed sunfish		✓
Industrial	7/6/2010	blue gill sunfish		✓
Industrial	7/6/2010	largemouth bass	✓	
Industrial	7/6/2010	logperch darter	✓	
Industrial	7/6/2010	logperch darter	✓	

Table 3.4: Mean values for water quality and mean temperature of all sites.

Site	Mean DO (mg/L)	Mean % DO	Mean Conductivity (uS)	Mean pH	Mean Temp (°C)
Reference	6.9	79.05	208.8	7.3	22.18
Landfill	6.3	71.28	241.8	6.9	24.07
Westinghouse	6.8	77.44	224.5	7.2	22.44
Residential Effluent	7.3	84.41	246.0	8.1	22.90
Industrial	7.1	84.13	275.0	7.6	23.55

Index of Biotic Integrity

The Index of Biotic Integrity developed by Karr (1981) is among the more widely used assessment methods for fish community analysis. The original IBI consisted of twelve metric components. There are six metrics used to evaluate species richness and composition including number of species, number of darter species, number of sucker species, number of sunfish species, and number of intolerant species and proportion of green sunfish. There are also three metrics used to evaluate trophic composition which include proportion of omnivores, proportion of insectivores and proportion of piscivores. Finally there are three metrics used to evaluate fish abundances and condition information which include number of individuals in the sample, proportion of hybrids and proportion of individuals with disease (U.S EPA 1990).

At many of the sampling locations, pollution intolerant species such as the northern hogsucker and the banded darter were present. For IBI classification, sites which include both the northern hogsucker and the banded darter and display species richness somewhat below expected levels especially due to loss of many pollution intolerant species as well as some species with less than optimal abundances or size distribution have been classified as good (Table: 3.4). Sites that have only one of these two species and display signs of further deterioration including fewer pollution intolerant forms and a trophic structure showing signs of being skewed or lacking the proper ratio of trophic levels and older age classes of top predators may be rare or not present have been classified as fair. Sites which have neither species present nor display signs of further deterioration including fewer pollution intolerant forms and the trophic structure showing signs of being skewed and older age classes of top predators may be rare or not present have been classified as poor. One site, the Westinghouse on July 6, 2010 failed to yield any fish and is therefore classified as no fish. In addition to these parameters number of individuals with disease, number of sunfish species and number of sucker species were also used in the IBI classification of each site (Karr 1981). While there are several fish species found within every site there are anthropogenic factors associated with surrounding land use that may be causing both disease and an inhibition of community structure among the resident fish assemblages. However the Shenango River has been remediated at multiple sites, for example the Westinghouse site, and it is unknown to what degree remnants of past water quality degradation may still be effecting fish species diversity. This makes evaluation of effects of varying current land use practices on fish species diversity more difficult to determine.

In a study done by the Pennsylvania Fish and Boat Commission (Wilson 2007) sampled 54 species from four different sites between the confluence of the Little Shenango River, north of the Lake to the Shenango dam. This study was located north west of the sites for this study and contained a lake ecosystem allowing increasing the species richness potential. The study used electro towboat gear and was conducted between 4/10/1990 and 6/25/2007. This sampling data is the only accessible record of fish species composition and it is the closest location to the sites chosen for this study. The number of fish species sampled in these areas is more than twice of that which was sampled in this study. There are several reasons for these results. The Pennsylvania Fish and Boat Commission study was done using electrical fishing gear which temporarily stuns all fish within the vicinity allowing accurate data reflecting local fish diversity to catch larger fish species (Wilson 2007). However, electro fishing is biased in that benthic species without swim bladders will not be sampled. In contrast, this study uses seine nets which are rarely able to catch benthic species unless they are disturbed with kick seining. Even when benthic species are disturbed toward the nets they often are able to slip underneath. A combination of sampling methods is needed to account for bias in future studies. Therefore, the lack of species in this study does not necessarily mean that the river is extremely polluted or degraded of species richness and diversity of fish. Data from the Pennsylvania Fish and Boat Commission displays a diverse local fish assemblage that is comprised of all trophic levels including top predators such as the Muskellunge and benthic omnivores such as darters and suckers (Wilson 2007). Their data also includes all of the twenty fish species sampled in this study. However, they do not provide information on the health of these fish and if they have any illness or disease. Furthermore with twenty species sampled in only a two year period, it is likely that sampling efforts are somewhat representative of the entire fish community.

During different times of the summer it is easy to see variations in the data especially in the number and types of species sampled. Some sites displayed variations in algae content and water clarity toward the later summer months. In addition, flow regimes were altered by presence or lack of rain. These factors in combination with the inconsistency of the seine net sampling method and resulting bias could yield inaccurate representations of certain sites. This accounts for the fluctuations in the IBI classifications of some sites from sampling date to sampling date. Therefore IBI results are relevant yet subjective. For example the reference site was chosen because it is thought to be a low impact site. During most of the summer this site yielded high numbers of multiple species resulting in fair to good IBI classification. Yet some results, specifically July 6, 2010, were very low resulting in poor IBI classification. This is seemingly due to seasonal variation of water characteristics such as flow regimes and suspended sediment. The other four sites show the same variation of classification during different times of the year for similar reasons.

Table 3.5: Six metrics used to evaluate IBI classification for sites alsong the Shenango River, PA.

Site	Date	# of sp.	# of Sunfish sp.	# sucker sp.	# with disease	Intolerant hogs-sucker	Intolerant banded darter	IBI Class
Reference	July 14-17, 2009	8	0	0	3	present	present	**good**
Industrial		5	1	0	0	present	absent	**fair**
Landfill		11	0	0	0	present	absent	**good**
Residential		2	0	0	0	present	absent	**poor**
Reference	Aug. 10-11, 2009	4	0	0	0	present	absent	**fair**
Industrial		5	1	0	2	present	absent	**fair**
Residential		5	0	0	0	present	absent	**fair**
Landfill		3	0	0	0	absent	absent	**poor**
Westinghouse		5	1	1	1	absent	absent	**poor**
Reference	Sept. 25, 2009	5	1	0	0	absent	absent	**fair**
Industrial		6	1	0	1	present	absent	**fair**
Landfill		3	0	0	0	absent	absent	**poor**
Residential		3	0	0	0	present	absent	**poor**
Westinghouse		7	2	0	2	present	absent	**fair**
Reference	June 2, 2010	4	0	0	0	absent	present	**fair**
Industrial		4	2	0	0	absent	absent	**poor**
Landfill		3	0	0	0	absent	absent	**poor**
Residential		3	0	0	0	absent	present	**poor**
Westinghouse		3	0	0	0	Present	absent	**fair**
Reference	June 22, 2010	3	0	0	0	present	present	**good**
Industrial		5	1	0	2	absent	absent	**poor**
Landfill		6	1	0	0	absent	absent	**fair**
Residential		2	0	0	0	Present	absent	**poor**
Westinghouse		4	1	0	1	absent	absent	**poor**
Reference	July 6, 2010	4	0	0	0	absent	absent	**poor**
Industrial		4	2	0	3	absent	absent	**poor**
Landfill		3	0	0	0	absent	absent	**poor**
Residential		2	0	0	0	absent	absent	**poor**
Westinghouse		0	0	0	0	absent	absent	**no fish**

Additive Partitioning

Additive partitioning is an operational method which allows the analysis of patterns of species diversity across multiple scales and is usually expressed by the number of species or species richness. The total or gamma diversity found in a pooled set of communities sampled from the river at any scale can be partitioned into the average diversity occurring within a sample (alpha diversity) and the average diversity among samples (beta diversity) (Pegg and Taylor 2007).

By applying quantitative analysis such as additive partitioning the average species diversity of Shannon's index (alpha diversity) of each site can be compared to another by taking average diversity within a site and adding it to the diversity found among another site (beta diversity). By doing this the overall or gamma diversity is determined for the two sites.

Alpha, beta and gamma diversity were evaluated for each impacted site as compared to the reference site (Table 3.6). Alpha diversity values (Shannon index) are an average of all sampling dates of a given site. Therefore they evaluate regional variation and do not take temporal variation within sites into account. Beta diversity values were much higher than alpha diversity values. This shows that there is more variation between sites than within sites. Therefore, between site diversity is contributing a substantial proportion of the gamma diversity at higher spatial scales, even perhaps, as large as the watershed. This displays the importance of protecting diversity at the larger level and improving the integrity of larger spatial scales (Pegg and Taylor 2007). All sites show numerous species unique to the site as compared to the reference site except the residential site which has only one. However there is variation within sites although the alpha diversity values are low. Therefore although beta diversity contributes a significant amount more to gamma diversity alpha diversity is still of importance. This suggests that some sites may be more conducive to particular species and therefore variation found within sites and among sites is of critical importance.

Table: 3.6 Alpha, Beta and Gamma Diversity for all sites as compared to the Reference site.

Site	Total # of Species	# of Sp. Unique to the Site	Alpha Diversity	Beta Diversity	Gamma Diversity
Reference	13	5	1.22	10	11.22
Landfill	13	4	1.00		11.00
Reference	13	6	1.22	10	11.22
Westinghouse	11	4	0.54		10.54
Reference	13	6	1.22	7	8.22
Residential	8	1	1.07		8.07
Reference	13	5	1.22	8	9.22
Industrial	11	3	0.82		8.82

Chapter 4 Conclusion

By evaluating the diversity of fish assemblages found within the Shenango River using additive partitioning, a modification of the IBI, species richness and species diversity indices it has been determined that while some sites may yield low numbers of species at certain times of years all sites have populations of several fish species. There was considerably more diversity found between all of the sampled sites than there was within sites seemingly due to variation environmental factors such as flow regime, substrate and depth from site to site. Beta diversity therefore is of critical importance when considering the anthropogenic impacts on fish communities and their diversity. However, there is variation within sites therefore alpha diversity is also relevant. Although alpha diversities (Shannon diversities) were very low for this study there is still variation of fish species composition within sites and the alpha diversity may increase over larger spatial scales.

Results of the IBI were varied and somewhat inconsistent for multiple reasons. Quality of some sites including the reference site showed considerable changes throughout the summer. Algae and slow moving water was found in several of the areas that were normally sampled. Sampling different areas within the site was difficult due to rapid flow rates, especially in the reference site. Therefore seasonal variation in water characteristics can alter fish diversity within sites. In addition, utilization of the IBI requires the assumption that samples are representative of the entire fish community. With the use of seine nets many larger fish are relatively impossible to catch due to their rapid bursts of speed and many smaller benthic species can simply go under the net reducing the number of species that can be caught using seining methods.

By taking the average of species richness we have determined that the landfill site has resulted in higher species richness than the reference site although Menhinick's was higher for the reference site. The industrial site had the next highest average species richness and was nearly as varied in species as the reference site. The Westinghouse site had considerably lower average species richness and the lowest diversity which is consistent with the state of the site. Finally the residential effluent site showed the lowest species richness. All sites had low species diversity (Shannon index < 1.5) indicating a need for further sampling.

Although sampling efforts were extended over a two year period and seem to be somewhat representative of the fish community there is no way of saying with any certainty that samples represent the entire community. This study has shown that there are multiple fish species inhabiting every site. However, the number of different species was often low and several fish caught at two of the sites displayed signs of disease. Fish communities within these sites seem to have an incomplete trophic structure. Lines of evidence for this consist of unevenly distributed percentage of omnivores, insectivores, herbivores and piscivores. Furthermore while there are several fish species found within every site both disease and parasitism can be seen among the resident fish assemblages.

Suggestions for future follow up studies

It is important to point out that this can be considered a preliminary study. A follow up study should be completed in order to draw solid conclusions on the state of fish diversity in the Shenango River and its association to varying types of land use. For future studies it is important to record the results of each seine sweep. This allows statistical analysis of each site. A combination of both seining and electro fishing for sampling efforts is suggested to ensure that samples are representative of the entire fish community and to account for the bias of each sampling method. For future studies it is important to note that approaching remediation at only the site scale would be insufficient. For future studies to properly evaluate the remediation efforts effect on the diversity of fish species, a larger spatial scale such as the entire watershed could be considered. This can be achieved by adding more sites and including headwaters. This would account for variation found both within sites and between sites. It is also important that water samples are tested for the presence of contaminants. Once contaminants present are identified an attempt can be made to connect them to land use around the sites or legacy contaminants. Once this is done determining the size and nature of sites such as the industrial site will be of critical importance.

All of these anthropogenic factors and many others can potentially alter the species richness and species diversity of fish assemblages found within the Shenango River. Therefore it is important that future studies determine what contaminants are found in the river and at what concentration. This will allow evaluation of fish diversity in relation to specific contaminants from specific land use and the ability to draw more solid conclusions as to which contaminants are having the greatest impact.

Chapter 5 References

Calculating Biodiversity "www.colby.edu/Biology." http://www.colby.edu/biology/BI131/Lab/Lab09CalcBiodivers.pdf. N.p., n.d. Web. 7 Aug 2010.

"Crawford County Conservation District." *http://www.crawfordconservation.com/watersheds.html*. Starn Marketing Group, 2007. Web. 8 Aug 2010.

Derickson , Craig. "Rapid Watershed Assessment Shenango Watershed." *United States Department of Agriculture* 1.29 (1993): n. pag. Web. 8 Aug 2010.

Google Earth "earth.google.com." *http://www.googleearth.com*. google, n.d. Web. 5 Aug 2010.

Hovance, Lisa. "Trumbull Soil and Water Conservation District." *http://www.swcd.co.trumbull.oh.us/swcd_contact.html*. Trumbull County IS Department, n.d. Web. 8 Aug 2010.

Karr, James. "Assessment of Biotic Integrity of Fish Communities." *Fisheries*. 6.6 (1981): 21-27.

Lyons, John. "A Fish-Based Index of Biotic Integrity to Assess Intermittent Headwater Streams in Wisconsin, USA." *Environmental Monitoring and Assessment*. 122. (2006): 239-258. Print.

Management and Buisness Administration"NetMBA.com." *http://www.netmba.com/*. Internet Center for Management and Business Administration, Inc., 2010. Web. 7 Aug 2010.

Morgan, Raymond. "Urbanization Effects on Stream Fish Assemblages in Maryland, USA." *North American Benthological*. 24.3 (2005): 643-655.

North American Gazeteer. N.p., 2009. Web. 25 Jul 2010. <reference.allrefer.com/gazetteer/S/S10145-shenango-river.html>.

Oberdorff, T. "Modification of an index of biotic integrity based on fish assemblages to characterize rivers in the Seine Basin, France." *Hydrobiologia*. 228. (1992): 117-130.

Oberdorff, Thierry. "Global scale patterns of species richness in rivers." *Ecography*. 18. (1995): 345-352.

Page, Lawrence. *Freshwater Fishes*. 1st. Boston New York: Houghton Mifflin Company, 1991. 1-432.

Paller, Micheal. "Effects of Ammonia and Chlorine on Fish in Streams Receiving Secondary Discharges." *Ecological Effects*. 55.8 (1983): 1087-1096.

Pegg, Mark. "Fish Species Diversity among spatial scales of Altered Temperate Rivers." *Jouranl of Biogeography*. 34. (2007): 549-558.

Peters, N. "Three types of Skin Papillomas of Flatfishes and Their causes." *Marine Ecology*. 1. (1979): 269-276.

Poulet, F.M. "Naturally Occurring Orocutaneous Papillomas and Carcinomas of Brown Bullheads in New York State." *Avian and Aquatic Animal Medicine*. 31. (1994): 8-18.

Sohier, Charolette. "Marine Biodiversity Wiki." *http://www.marbef.org/wiki/Measurements_of_biodiversity*. N.p., 09 17 2008. Web. 11 Aug 2010.

Sheldon, Andrew. "Conservation of Stream Fishes: Patterns of Diversity, Rarity, and Risk. *Conservation Biology*. 2.2 (1988): 149-159.

Stendera, Sonja and Richard Johnson. “Additive partitioning of aquatic invertebrate species diversity across multiple spatial scales.” Freshwater Biology. 50 (2005): 1360-1375.

United States Environmental Protection Agency (U.S. EPA). "National Program Guidance for Surface Waters." *Biological Criteria*. (1990): 30-67.

United States Environmental Protection Agency (U.S. EPA) “Mid Atlantic Superfund” (2010). Web. http://www.epa.gov/reg3hwmd/super/pa.htm. Accessed 10 August 2010.

Veech, Joseph. "The additive partitioning of species diversity: recent revival of an." *Mini-Review*. 99. (2002): 1-9. Print.

Wallace, Dominey. "Maintenance of Female Mimicry as a Reproductive Strategy in Bluegill Sunfish." *Environmental Biology of Fish*. 6.1 (1981): 59-64.

Walsh, Stephen. "Decline of North American Freshwater Fishes." *Action Bioscience* (2009): 1-7. Web. 25 Jan 2010.

Wilson, Jonathan. "Fish Gill Morphology: Inside and Out." *Journal of Experimental Zoology*. 293. (2002): 192-213.

Wilson, Timothy. Pennsylvania Fish and Boat Commission (2007)

Wood, Edward. "Definitive Diagnosis of Fish Mortalities." *Fish Pathology*. 6.9 (1960): 994-999.

Appendix

Table 1A: Menhinick's index values of Species Richness of all Sites from the Shenango River, PA.

Fish Species	Site	Sample Date	Number of Individuals	Menhinick's index
Blunt nose minnow	landfill	7/14/2009	9	2.04
Brook silversides	landfill	7/14/2009	4	
Emerald shiner	landfill	7/14/2009	11	
Johnny darter	landfill	7/14/2009	1	
Rainbow smelt	landfill	7/14/2009	1	
Small mouth bass	landfill	7/14/2009	11	
Spot tail minnow	landfill	7/14/2009	1	
Spot fin shiner	landfill	7/14/2009	2	
White perch	landfill	7/14/2009	1	
Yellow perch	landfill	7/14/2009	5	
Northern hogsucker	Residential effluent	7/14/2009	1	0.49
Spot fin shiner	Residential effluent	7/14/2009	16	
Banded darter	Reference	7/14/2009	4	1.95
Brook silversides	Reference	7/14/2009	3	
Emerald shiner	Reference	7/14/2009	2	
Johnny darter	Reference	7/14/2009	1	
Largemouth bass	Reference	7/14/2009	4	
Northern hogsucker	Reference	7/14/2009	1	
Spot fin shiner	Reference	7/14/2009	1	
Yellow perch	Reference	7/14/2009	1	
Pumpkinseed sunfish	Industrial	7/17/2009	7	1.35
Largemouth bass	Industrial	7/17/2009	5	
Northern hogsucker	Industrial	7/17/2009	4	
Smallmouth bass	Industrial	7/17/2009	1	
Spot fin shiner	Industrial	7/17/2009	4	
Brook silversides	Industrial	8/10/2009	2	0.78
Emerald shiner	Industrial	8/10/2009	23	
Pumpkinseed sunfish	Industrial	8/10/2009	8	
Northern hogsucker	Industrial	8/10/2009	5	
Smallmouth bass	Industrial	8/10/2009	3	
Carp	Residential effluent	8/10/2009	1	0.59
Emerald shiner	Residential effluent	8/10/2009	33	
Northern hogsucker	Residential effluent	8/10/2009	9	
Spot tail shiner	Residential effluent	8/10/2009	2	

Fish Species	Site	Sample Date	Number of Individuals	Menhinick's index
Emerald shiner	Reference	8/11/2009	3	0.75
Largemouth bass	Reference	8/11/2009	15	
Northern hogsucker	Reference	8/11/2009	3	
Spot tail shiner	Reference	8/11/2009	7	
Largemouth bass	landfill	8/11/2009	10	0.71
Rainbow smelt	landfill	8/11/2009	2	
Yellow perch	landfill	8/11/2009	6	
Pumpkinseed sunfish	Westinghouse	8/11/2009	1	0.80
Rainbow smelt	Westinghouse	8/11/2009	1	
Small mouth bass	Westinghouse	8/11/2009	1	
Spot tail shiner	Westinghouse	8/11/2009	35	
White sucker	Westinghouse	8/11/2009	1	
Blue gill sunfish	Reference	9/25/2009	1	0.78
Emerald shiner	Reference	9/25/2009	17	
Largemouth bass	Reference	9/25/2009	3	
Spot tail shiner	Reference	9/25/2009	5	
Yellow perch	Reference	9/25/2009	4	
Largemouth bass	Landfill	9/25/2009	3	0.95
Emerald shiner	Landfill	9/25/2009	5	
Yellow perch	Landfill	9/25/2009	2	
Blue gill sunfish	Westinghouse	9/25/2009	2	1.7
Emerald shiner	Westinghouse	9/25/2009	2	
Largemouth bass	Westinghouse	9/25/2009	2	
Northern hogsucker	Westinghouse	9/25/2009	1	
Smallmouth bass	Westinghouse	9/25/2009	2	
Emerald shiner	Residential effluent	9/25/2009	4	0.87
Northern hogsucker	Residential effluent	9/25/2009	7	
Spot fin shiner	Residential effluent	9/25/2009	1	
Emerald shiner	Industrial	9/25/2009	10	1.15
Largemouth bass	Industrial	9/25/2009	3	
Pumpkinseed sunfish	Industrial	9/25/2009	7	
Smallmouth bass	Industrial	9/25/2009	4	
Yellow perch	Industrial	9/25/2009	1	
Northern hogsucker	Industrial	9/25/2009	2	

Fish Species	Site	Sample Date	Number of Individuals	Menhinick's index
Madtom stonecat	Reference	6/2/2010	1	1.26
Banded darter	Reference	6/2/2010	3	
Greenside darter	Reference	6/2/2010	3	
Spot fin shiner	Reference	6/2/2010	3	
Rainbow smelt	landfill	6/2/2010	1	0.53
Emerald shiner	landfill	6/2/2010	14	
Yellow perch	landfill	6/2/2010	17	
Northern hogsucker	Westinghouse	6/2/2010	5	0.70
Smallmouth bass	Westinghouse	6/2/2010	1	
Spot fin shiner	Westinghouse	6/2/2010	12	
Emerald shiner	Residential effluent	6/2/2010	1	0.90
Greenside darter	Residential effluent	6/2/2010	8	
Johnny darter	Residential effluent	6/2/2010	2	
Pumpkinseed sunfish	Industrial	6/2/2010	8	1.20
Largemouth bass	Industrial	6/2/2010	1	
Rainbow smelt	Industrial	6/2/2010	1	
Bluegill sunfish	Industrial	6/2/2010	1	
Greenside darter	Reference	6/22/2010	2	1.73
Banded darter	Reference	6/22/2010	1	
Northern hogsucker	Reference	6/22/2010	1	
Emerald shiner	landfill	6/22/2010	30	0.92
Blue gill sunfish	landfill	6/22/2010	1	
Spot fin shiner	landfill	6/22/2010	1	
Largemouth bass	landfill	6/22/2010	3	
Johnny darter	landfill	6/22/2010	2	
Yellow perch	landfill	6/22/2010	5	
Pumpkinseed sunfish	Westinghouse	6/22/2010	1	1.26
Largemouth bass	Westinghouse	6/22/2010	1	
Emerald shiner	Westinghouse	6/22/2010	7	
Yellow perch	Westinghouse	6/22/2010	2	
Emerald shiner	Residential effluent	6/22/2010	10	0.57
Banded darter	Residential effluent	6/22/2010	2	

Fish Species	Site	Sample Date	Number of Individuals	Menhinick's index
Pumpkinseed sunfish	Industrial	6/22/2010	15	0.92
Largemouth bass	Industrial	6/22/2010	1	
Blue gill sunfish	Industrial	6/22/2010	6	
Emerald shiner	Industrial	6/22/2010	4	
Brook silversides	Industrial	6/22/2010	3	
Emerald shiner	Reference	7/6/2010	81	0.41
Spot fin shiner	Reference	7/6/2010	7	
Yellow perch	Reference	7/6/2010	2	
Log perch darter	Reference	7/6/2010	1	
Largemouth bass	landfill	7/6/2010	4	1.13
Yellow perch	landfill	7/6/2010	1	
Emerald shiner	landfill	7/6/2010	2	
No fish	Westinghouse	7/6/2010	0	0
Emerald shiner	Residential effluent	7/6/2010	13	0.75
Spot fin shiner	Residential effluent	7/6/2010	2	
Greenside darter	Residential effluent	7/6/2010	1	
Pumpkinseed sunfish	Industrial	7/6/2010	17	0.78
Blue gill sunfish	Industrial	7/6/2010	2	
Largemouth bass	Industrial	7/6/2010	3	
Log perch darter	Industrial	7/6/2010	4	

Table 2A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 7/14/2009.

Fish Species	**Number of Individuals**	**(p1)**	**[ln(p1)]**	**(p1) [ln(p1)]**
Banded darter	4	0.24	1.45	0.340
Brook silversides	3	0.18	1.73	0.306
Emerald shiner	2	0.12	2.14	0.252
Johnny darter	1	0.06	2.83	0.167
Largemouth bass	4	0.24	1.45	0.340
Northern hogsucker	1	0.06	2.83	0.167
Spot fin shiner	1	0.06	2.83	0.167
Yellow perch	1	0.06	2.83	0.167
Total	**17**	**1.00**		**1.905**

Table 3A: Shannon Index for Species Diversity of the Shenango River Industrial Site from sampling date 7/17/2009.

Fish Species	**Number of Individuals**	**(p1)**	**[ln(p1)]**	**(p1) [ln(p1)]**
Pumpkinseed sunfish	7	0.33	1.10	0.37
Largemouth bass	5	0.24	1.44	0.34
Northern hogsucker	4	0.19	1.66	0.32
Smallmouth bass	1	0.05	3.04	0.14
Spot fin shiner	4	0.19	1.66	0.32
Total	**21**	**1.00**		**1.48**

Table 4A: Shannon Index for Species Diversity of the Shenango River landfill site from sampling date 7/14/2009.

Fish Species	**Number of Individuals**	**(p1)**	**[ln(p1)]**	**(p1) [ln(p1)]**
Blunt nose minnow	9	0.20	1.63	0.319
Brook silversides	4	0.09	2.44	0.142
Emerald shiner	11	0.24	1.43	0.390
Johnny darter	1	0.02	3.83	0.035
Rainbow smelt	1	0.02	3.83	0.035
Small mouth bass	11	0.24	1.43	0.390
Spot tail minnow	1	0.02	3.83	0.035
Spot fin shiner	2	0.04	3.14	0.071
White perch	1	0.02	3.83	0.035
Yellow perch	5	0.11	2.22	0.177
Total	**46**	**1.00**		**1.631**

Table 5A: Shannon Index for Species Diversity of the Shenango River Residential Effluent Site from sampling date 7/14/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Northern hogsucker	1	0.06	2.83	0.167
Spot fin shiner	16	0.94	0.06	0
Total	**17**	**1.00**		**0.455**

Table 6A: Shannon Index for Species Diversity of the Shenango River Industrial Site from sampling date 8/10/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Brook silversides	2	0.05	3.02	0.147
Emerald shiner	23	0.56	0.58	1.694
Pumpkinseed sunfish	8	0.20	1.63	0.589
Northern hogsucker	5	0.12	2.10	0.368
Smallmouth bass	3	0.07	2.61	0.221
Total	**41**	**1.00**		**0.878**

Table 7A: Shannon Index for Species Diversity of the Shenango River Residential Effluent Site from sampling date 8/10/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Carp	1	0.02	3.81	0.085
Emerald shiner	33	0.73	0.31	2.792
Northern hogsucker	9	0.20	1.61	0.761
Spot tail shiner	2	0.04	3.11	0.169
Total	**45**	**1.00**		**3.807**

Table 8A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 8/11/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	3	0.11	2.23	0.239
Largemouth bass	15	0.54	0.62	1.197
Northern hogsucker	3	0.11	2.23	0.239
Spot tail shiner	7	0.25	1.39	0.558
Total	**28**	**1.00**		**2.234**

Table 9A: Shannon Index for Species Diversity of the Shenango River Landfill Site from sampling date 8/11/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Largemouth bass	10	0.56	0.588	0.327
Rainbow smelt	2	0.11	2.197	0.065
Yellow perch	6	0.33	1.099	0.196
Total	**18**	**1.00**		**0.588**

Table 10A: Shannon Index for Species Diversity of the Shenango River Westinghouse Site from sampling date 8/11/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Pumpkinseed sunfish	1	0.03	3.66	0.094
Rainbow smelt	1	0.03	3.66	0.094
Small mouth bass	1	0.03	3.66	0.094
Spot tail shiner	35	0.90	0.11	0.097
White sucker	1	0.03	3.66	0.094
Total	**39**	**1.00**		**0.473**

Table 11A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 9/25/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Blue gill sunfish	1	0.03	3.40	0.113
Emerald shiner	17	0.57	0.57	0.322
Largemouth bass	3	0.10	2.30	0.230
Spot tail shiner	5	0.17	1.79	0.299
Yellow perch	4	0.13	2.01	0.269
Total	**30**	**1.00**		**1.233**

Table 12A: Shannon Index for Species Diversity of the Shenango River Landfill Site from sampling date 9/25/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Largemouth bass	3	0.30	1.20	0.361
Emerald shiner	5	0.50	0.69	0.602
Yellow perch	2	0.20	1.61	0.241
Total	10	1.00		1.204

Table 13A: Shannon Index for Species Diversity of the Shenango River Westinghouse Site from sampling date 9/25/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Blue gill sunfish	2	0.22	1.504	0.334
Emerald shiner	2	0.22	1.504	0.334
Largemouth bass	2	0.22	1.504	0.334
Northern hogsucker	1	0.11	2.197	0.167
Smallmouth bass	2	0.22	1.504	0.334
Total	**44**			**1.4310.956**

Table 14A: Shannon Index for Species Diversity of the Shenango River Residential Effluent Site from sampling date 9/25/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	4	0.33	1.099	0.366
Northern hogsucker	7	0.58	0.539	0.641
spot fin shiner	1	0.08	2.485	0.092
Total	12	1.00		1.099

Table 15A: Shannon Index for Species Diversity of the Shenango River Industrial Site from sampling date 9/25/2009.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	10	0.37	0.993	0.368
Largemouth bass	3	0.11	2.197	0.110
Northern hogsucker	2	0.07	2.603	0.074
Pumpkin seed	7	0.26	1.350	0.258
Smallmouth bass	4	0.15	1.910	0.147
yellow perch	1	0.04	3.296	0.037
Total	27	1.00		0.993

Table 16A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 6/2/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Madtom stonecat	1	0.1	2.30	0.230
Banded darter	3	0.3	1.20	0.361
Greenside darter	3	0.3	1.20	0.361
Spot fin shiner	3	0.3	1.20	0.361
Total	**10**	**1**		**1.314**

Table 17A: Shannon Index for Species Diversity of the Shenango River landfill site from sampling date 6/2/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Rainbow smelt	1	0.03	3.47	0.108
Emerald shiner	14	0.44	0.83	0.362
Yellow perch	17	0.53	0.63	0.336
Total	**32**	**1.00**		**0.806**

Table 18A: Shannon Index for Species Diversity of the Shenango River Westinghouse site from sampling date 6/2/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Northern hogsucker	5	0.05	3	0.15
Smallmouth bass	1	0.01	4.6	0.046
Spot fin shiner	12	0.12	2.1	0.252
Total	18	0.18		0.448

Table 19A: Shannon Index for Species Diversity of the Shenango River Residential effluent site from sampling date 6/2/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	1	0.01	4.6	0.046
Greenside darter	8	0.08	2.5	0.2
Johnny darter	2	0.02	3.9	0.078
Total	**11**	**0.11**		**0.324**

Table 20A: Shannon Index for Species Diversity of the Shenango River Industrial site from sampling date 6/2/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Pumpkinseed sunfish	8	0.08	2.5	0.2
Largemouth bass	1	0.01	4.6	0.046
Rainbow smelt	1	0.01	4.6	0.046
Bluegill sunfish	1	0.01	4.6	0.046
Total	**11**	**0.11**		**0.338**

Table 21A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 6/22/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Greenside darter	2	0.02	3.9	0.078
Banded darter	1	0.01	4.6	0.046
Northern hogsucker	1	0.01	4.6	0.046
Total	**4**	**0.04**		**0.17**

Table 22A: Shannon Index for Species Diversity of the Shenango River Landfill Site from sampling date 6/22/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	30	0.3	1.2	0.36
Blue gill sunfish	1	0.01	4.6	0.046
Spot fin shiner	1	0.01	4.6	0.046
Largemouth bass	3	0.03	3.5	0.105
Johnny darter	2	0.02	3.9	0.078
Yellow perch	5	0.05	3	0.15
Total	**42**	**0.42**		**0.785**

Table 23A: Shannon Index for Species Diversity of the Shenango River Westinghouse Site from sampling date 6/22/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Pumpkinseed sunfish	1	0.01	4.6	0.046
Largemouth bass	1	0.01	4.6	0.046
Emerald shiner	7	0.07	2.6	0.128
Yellow perch	2	0.02	3.9	0.078
Total	**11**	**0.11**		**0.298**

Table 24A: Shannon Index for Species Diversity of the Shenango River Residential Effluent Site from sampling date 6/22/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	10	0.83	0.187	0.155
Banded darter	2	0.17	1.771	0.301
Total	**2**	**1.00**		**0.456**

Table 25A: Shannon Index for Species Diversity of the Shenango River Industrial Site from sampling date 6/22/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Pumpkinseed sunfish	15	0.15	1.9	0.285
Largemouth bass	1	0.01	4.6	0.046
Blue gill sunfish	6	0.06	2.8	0.168
Emerald shiner	4	0.04	3.2	0.128
Brook silversides	3	0.03	3.5	0.105
Total	**29**	**0.29**		**0.732**

Table 26A: Shannon Index for Species Diversity of the Shenango River Reference Site from sampling date 7/6/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald Shiner	81	0.86	0.149	0.128
Spot fin shiner	10	0.11	2.24	0.238
Yellow perch	2	0.02	3.85	0.082
Log perch darter	1	0.01	4.54	0.048
Total	94	1.00		0.497

Table 27A: Shannon Index for Species Diversity of the Shenango River Landfill Site from sampling date 7/6/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Largemouth Bass	4	0.57	0.560	0.320
Yellow perch	1	0.14	1.95	0.278
Emerald shiner	2	0.29	1.25	0.358
Total	7	1.00		0.956

Table 28A: Shannon Index for Species Diversity of the Shenango River Westinghouse Site from sampling date 7/6/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
No Fish	0	0	0	0

Table 29A: Shannon Index for Species Diversity of the Shenango River Residential effluent Site from sampling date 7/6/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Emerald shiner	13	0.81	0.208	0.169
Spot fin shiner	2	0.13	2.079	0.060
Green side darter	1	0.06	2.773	0.023
Total	16	1.00		0.251

Table 30A: Shannon Index for Species Diversity of the Shenango River Industrial Site from sampling date 7/6/2010.

Fish Species	Number of Individuals	(p1)	[ln(p1)]	(p1) [ln(p1)]
Pumpkin seed	15	0.63	0.470	0.294
Blue gill sunfish	2	0.08	2.485	0.039
Largemouth bass	3	0.13	2.079	0.059
Log perch darter	4	0.17	1.792	0.078
Total	24	1.00		0.470

Table 31A: Common name, scientific name and trophic order for all species caught in the Shenango River during the June 2009 to July 2010 sampling period

Common name	Scientific Name	Trophic order
Blunt nose minnow	*Pimephales notatus*	Planktivore/insectivore
Brook silversides	*Labidesthes sicculus*	insectivore
Emerald shiner	*Notropis atherinoides*	Planktivore/insectivore
Johnny darter	*Etheostoma nigrum*	insectivore
Rainbow smelt	*Osmerus mordax*	omnivore
Small mouth bass	*Micropterus dolomieu*	omnivore
Spot tail minnow	*Notropis hudsonius*	insectivore
Spot fin shiner	*Cyprinella spiloptera*	insectivore
White perch	*Morone americana*	piscivore
Pumpkinseed sunfish	*Lepomis gibbosus*	omnivore
Madtom stonecat	*Noturus flavus*	omnivore
Banded darter	*Sympetrum pedemontanum*	insectivore
Greenside darter	*Etheostoma blenniodes*	insectivore
White sucker	*Catostomus commersonii*	omnivore
Blue Gill sunfish	*Lepomis macrochirus*	omnivore
Log perch darter	*Percina caprodes*	insectivore
Yellow perch	*Perca flavescens*	insectivore
Common carp	*Cyprinus carpio*	omnivore
Northern hogsucker	*Hypentelium nigricans*	Planktivore/insectivore
Largemouth bass	*Micropterus salmoides*	omnivore

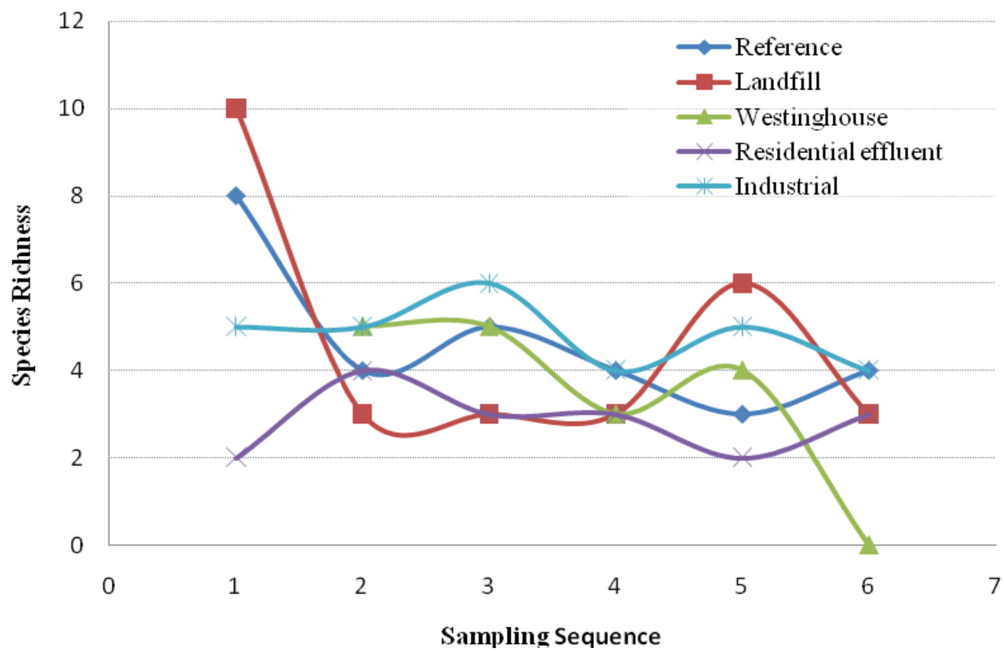

Figure 1A: The Species Richness of Sampling Sequence (date) for Each Site. Sampling sequence 1=7/14-7/16/2009; 2=8/10-8/11/2009; 3=9/25/2009; 4=6/2/2010; 5=6/22/2010; 6=7/6/2010

Table: 32A Raw Water Qualities and Number of Fishes Caught At each Site in the Shenango River during June 2009 to July 2010

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Landfill Site	7/14/2009	Blunt Nose Minnow	2.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.7	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.4	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	3	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Blunt Nose Minnow	2.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Brook Silversides	3.2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Brook Silversides	3.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Brook Silversides	3.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Brook Silversides	1.7	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	4.2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	4.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	6	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	5.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	4.8	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	6.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	5.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Emerald Shiner	4.2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Johnny Darter	3.4	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	N. Hogsucker	4.8	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Rainbow Smelt	9.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	7	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	6	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.3	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	4	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.3	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	4.5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.5	6.32	73.8	194	6.73	78.5	23.6

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Landfill Site	7/14/2009	Sm. Mouth Bass	5.6	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Sm. Mouth Bass	5.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Spot Tail Minnow	3.1	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Spotfin Shiner	5	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Spotfin Shiner	5.9	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	White Perch	4.2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Yellow Perch	4.6	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Yellow Perch	5.2	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Yellow Perch	5.4	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Yellow Perch	4.9	6.32	73.8	194	6.73	78.5	23.6
Landfill Site	7/14/2009	Yellow Perch	5.6	6.32	73.8	194	6.73	78.5	23.6
Residential Site	7/14/2009	N Hogsucker	5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	10	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	7.5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	9	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	9.5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	4.5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	9	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	4.9	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	8.6	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	7	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	7	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6.5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6.5	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	7.8	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6	7.44	87.9	218.1	8.86	33.5	24
Residential Site	7/14/2009	Spotfin Shiner	6.5	7.44	87.9	218.1	8.86	33.5	24
Reference Site	7/14/2009	Banded Darter	5.2	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Banded Darter	5.2	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Banded Darter	4.8	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Banded Darter	3	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Brook Silversides	4.3	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Brook Silversides	3.2	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Brook Silversides	3.7	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Emerald Shiner	4	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Emerald Shiner	5.5	6.9	80.9	191.5	6.44	37.5	23.2

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference Site	7/14/2009	Johnny Darter	2.8	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Lg. Mouth Bass	6.5	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Lg. Mouth Bass	5	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Lg. Mouth Bass	6.7	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Lg. Mouth Bass	6.1	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	N. Hogsucker	5.5	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Spotfin Shiner	6.4	6.9	80.9	191.5	6.44	37.5	23.2
Reference Site	7/14/2009	Yellow Perch	5.4	6.9	80.9	191.5	6.44	37.5	23.2
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	12	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	13.8	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	14	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	13	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	17	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	12	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Gr. Sunfish (tumor)	12.5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Lg. Mouth Bass	7	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Lg. Mouth Bass	6	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Lg. Mouth Bass	7.5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Lg. Mouth Bass	6.7	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Lg. Mouth Bass	7	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	N. Hogsucker	6.5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	N. Hogsucker	5.6	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	N. Hogsucker	5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	N. Hogsucker	4.5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Sm. Mouth Bass	4.5	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Spotfin Shiner	8	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Spotfin Shiner	8	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Spotfin Shiner	9	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	7/17/2009	Spotfin Shiner	7	6.4	76.1	236.4	8.47	34	23.7
Industrial Site	8/10/2009	Brook Silversides	6	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Brook Silversides	3	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8.7	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.2	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Industrial Site	8/10/2009	Emerald Shiner	6.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	6.3	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	6.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.2	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.6	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	7	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Emerald Shiner	8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	17	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	8.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	14	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	11	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	1	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	8.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish	9.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Gr. Sunfish (tumor)	16.8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	N. Hogsucker	6.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	N. Hogsucker	6.8	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	N. Hogsucker	5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	N. Hogsucker	7.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	N. Hogsucker	3	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Sm. Mouth Bass	6.5	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Sm. Mouth Bass	6	6.63	80	243.8	6.95	71	25.7
Industrial Site	8/10/2009	Sm. Mouth Bass	6	6.63	80	243.8	6.95	71	25.7
Residential Site	8/10/2009	Carp	26.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.2	6.43	76.7	205.9	8.85	54	24.1

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Residential Site	8/10/2009	Emerald Shiner	8.2	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	9	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	9	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	7	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	7.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	9.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	7.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	7	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Emerald Shiner	5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Johnny Darter	4.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	8	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	6.2	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	7.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	6.5	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	7.5	6.43	76.7	205.9	8.85	54	24.1

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Residential Site	8/10/2009	N. Hogsucker	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	N. Hogsucker	6	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Spottail Shiner	7	6.43	76.7	205.9	8.85	54	24.1
Residential Site	8/10/2009	Spottail Shiner	7	6.43	76.7	205.9	8.85	54	24.1
Reference Site	8/11/2009	Emerald Shiner	7	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Emerald Shiner	9.5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Emerald Shiner	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	9	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	6	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	7.5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	9	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	6	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	9	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	9.1	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	9.7	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	6.5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	8	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Lg. Mouth Bass	6	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	N. Hogsucker	6	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	N. Hogsucker	6	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	N. Hogsucker	7.5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	9	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	4	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	4.5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	5	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	4.3	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	3	6.6	77.9	195.1	8.27	64	24.5
Reference Site	8/11/2009	Spottail Shiner	5	6.6	77.9	195.1	8.27	64	24.5
landfill Site	8/11/2009	Lg. Mouth Bass	6	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	7	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6	5.78	70.2	198.8	7.91	48	24.6

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Landfill Site	8/11/2009	Lg. Mouth Bass	6	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	7	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Lg. Mouth Bass	6.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Rainbow Smelt	3.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Rainbow Smelt	6.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	2.7	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	2.5	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	3	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	2	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	2	5.78	70.2	198.8	7.91	48	24.6
Landfill Site	8/11/2009	Yellow Perch	3	5.78	70.2	198.8	7.91	48	24.6
Westinghouse Site	8/11/2009	Gr. Sunfish	9.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Rainbow Smelt	5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Sm. Mouth Bass	6	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	4	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	2.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	2.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.4	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	4	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	4.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	2.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.7	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	3.6	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	1.5	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	1.2	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	1.6	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Spottail Shiner	1	5.79	68.5	209.2	7.79	71	24
Westinghouse Site	8/11/2009	Wh. Sucker (spots)	6.6	5.79	68.5	209.2	7.79	71	24
Reference site	9/25/2009	Bluegill Sunfish	11.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	4.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	4	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	2.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	4	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	2.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	4	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	3	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	8	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	8	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	7	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	7	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Emerald Shiner	7.4	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Lg. Mouth Bass	8	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Lg. Mouth Bass	7	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Lg. Mouth Bass	7	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Spottail Shiner	8.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Spottail Shiner	9.5	6.89	77.1	197.3	8.51	69	21.1

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference site	9/25/2009	Spottail Shiner	8	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Spottail Shiner	6	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Spottail Shiner	5.5	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Spottail Shiner	4	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Yellow Perch	3	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Yellow Perch	3	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Yellow Perch	2.7	6.89	77.1	197.3	8.51	69	21.1
Reference site	9/25/2009	Yellow Perch	2.7	6.89	77.1	197.3	8.51	69	21.1
Landfill	9/25/2009	Lg. Mouth Bass	8	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Lg. Mouth Bass	7	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Lg. Mouth Bass	7	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Emerald Shiner	8	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Emerald Shiner	8	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Emerald Shiner	7	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Emerald Shiner	7	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Emerald Shiner	7.4	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Yellow Perch	2.7	6.04	67.6	200.1	7.47	48	21
Landfill	9/25/2009	Yellow Perch	2.7	6.04	67.6	200.1	7.47	48	21
Westinghouse Site	9/25/2009	Bluegill Sunfish	4	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Bluegill Sunfish	6.5	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Emerald Shiner	7.2	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Emerald Shiner	9	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Lg. Mouth Bass	10	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Lg. Mouth Bass	8.5	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	N. Hogsucker	9	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Sm. Mouth Bass	7	5.56	73.3	245.6	8.17	58	20.6
Westinghouse Site	9/25/2009	Sm. Mouth Bass	6	5.56	73.3	245.6	8.17	58	20.6
Residential Site	9/25/2009	Emerald Shiner	7.5	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	Emerald Shiner	9	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	Emerald Shiner	4	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	Emerald Shiner	4.5	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	12	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	10	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	9.5	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	12	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	10	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	N. Hogsucker	10	8.27	93.5	224.9	8.94	22	21.3

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Residential Site	9/25/2009	N. Hogsucker	9	8.27	93.5	224.9	8.94	22	21.3
Residential Site	9/25/2009	Spot Tail Shiner	4	8.27	93.5	224.9	8.94	22	21.3
Industrial Site	9/25/2009	Emerald Shiner	7	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	7	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	7.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	7.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	4.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	7.2	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	10	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	7.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Emerald Shiner	9.3	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Lg. Mouth Bass	10.1	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Lg. Mouth Bass	9	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Lg. Mouth Bass	7.3	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	N. Hogsucker	7.3	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	N. Hogsucker	8.1	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	14	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	12.6	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	14.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	12	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	13	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	12.5	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Pumpkin Seed	13	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Sm. Mouth Bass	7.8	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Sm. Mouth Bass	8.2	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Sm. Mouth Bass	6.6	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Sm. Mouth Bass	7.6	7.4	83.6	230.3	8.9	60	21.4
Industrial Site	9/25/2009	Yellow Perch	3.2	7.4	83.6	230.3	8.9	60	21.4
Reference Site	6/2/2010	Madtom Stonecat	17	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Banded Darter	8	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Banded Darter	8	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Banded Darter	6	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Greenside Darter	7.3	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Greenside Darter	7	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Greenside Darter	6.5	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Spotfin Shiner	4.5	8.69	88.3	167.5	7.01	32	17.4

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference Site	6/2/2010	Spotfin Shiner	5	8.69	88.3	167.5	7.01	32	17.4
Reference Site	6/2/2010	Spotfin Shiner	4	8.69	88.3	167.5	7.01	32	17.4
Landfill site	6/2/2010	Rainbow Smelt	6.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	5.9	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	7.6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	5.7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Emerald Shiner	6.7	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	3.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	3.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	3.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	3.5	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Landfill site	6/2/2010	Yellow Perch	4	7.57	82.5	213.1	7.15	42	22.4
Westinghouse Site	6/2/2010	N. Hogsucker	16	9.71	97.9	178.6	7.07	78	18.8

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Westinghouse Site	6/2/2010	N. Hogsucker	11.5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	N. Hogsucker	12	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	N. Hogsucker	12	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	N. Hogsucker	10	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Sm. Mouth Bass	9	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	6	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5.5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5.5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5.7	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	4	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5.5	9.71	97.9	178.6	7.07	78	18.8
Westinghouse Site	6/2/2010	Spotfin Shiner	5	9.71	97.9	178.6	7.07	78	18.8
Residential Site	6/2/2010	Emerald Shiner	9.3	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	6.5	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	5.5	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	5.5	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	5.6	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	5.8	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	6	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	5.5	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	Greenside Darter	6	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	johnny Darter	4.7	6.86	73.4	221.3	7.46	45	18.9
Residential Site	6/2/2010	johnny Darter	7.5	6.86	73.4	221.3	7.46	45	18.9
Industrial Site	6/2/2010	Pumpkin Seed	14.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	17	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	14.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	15.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	15.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	16	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	13.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Pumpkin Seed	14.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Lg. Mouth Bass	12.5	7.61	85.0	246	6.65	87	20.1

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Industrial Site	6/2/2010	Rainbow Smelt	11.5	7.61	85.0	246	6.65	87	20.1
Industrial Site	6/2/2010	Bluegill Sunfish	21	7.61	85.0	246	6.65	87	20.1
Reference site	6/22/2010	Greenside Darter	9.5	6.4	73.6	178.4	6.42	36	21.9
Reference site	6/22/2010	Greenside Darter	6.5	6.4	73.6	178.4	6.42	36	21.9
Reference site	6/22/2010	Banded Darter	7	6.4	73.6	178.4	6.42	36	21.9
Reference site	6/22/2010	N. Hogsucker	13	6.4	73.6	178.4	6.42	36	21.9
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	7	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	7	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	6	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	7	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	7	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Emerald Shiner	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Bluegill Sunfish	7	4.93	73.6	223.4	7.17	54	24.1

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Landfill site	6/22/2010	Spotfin Shiner	7	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Lg. Mouth Bass	4.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Lg. Mouth Bass	4	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Lg. Mouth Bass	4	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	johnny Darter	4.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	johnny Darter	3.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Yellow Perch	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Yellow Perch	5.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Yellow Perch	3	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Yellow Perch	2.5	4.93	73.6	223.4	7.17	54	24.1
Landfill site	6/22/2010	Yellow Perch	3	4.93	73.6	223.4	7.17	54	24.1
Westinghouse Site	6/22/2010	Pumpkin Seed	19.5	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Lg. Mouth Bass	14	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	6.5	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	6.5	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	6	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	6	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	7	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	5	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Emerald Shiner	5.5	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Yellow Perch	4	6.05	70.3	177.6	6.95	54	22.6
Westinghouse Site	6/22/2010	Yellow Perch	3	6.05	70.3	177.6	6.95	54	22.6
Residential site	6/22/2010	Emerald Shiner	9	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	9.5	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	10.5	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	8	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	8	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	7.5	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	9	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	10.5	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	8	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Emerald Shiner	7	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Banded Darter	6.5	7.4	86.4	245.9	7.41	34.5	22.9
Residential site	6/22/2010	Banded Darter	6	7.4	86.4	245.9	7.41	34.5	22.9
Industrial Site	6/22/2010	Pumpkin Seed	13	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	16	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	17	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	16.5	7.32	86.7	245.4	7.28	57	23.8

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Industrial Site	6/22/2010	Pumpkin Seed	17	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	14.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	15.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	15	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	18	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	14	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	14.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	15	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	12	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	16	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	13.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	12	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Pumpkin Seed	16.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Lg. Mouth Bass	12	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	19	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	14	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	18	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	18	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	16	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Bluegill Sunfish	11	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Emerald Shiner	10	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Emerald Shiner	10	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Emerald Shiner	6	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Emerald Shiner	5.5	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Brook Silversides	4	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Brook Silversides	4	7.32	86.7	245.4	7.28	57	23.8
Industrial Site	6/22/2010	Brook Silversides	4	7.32	86.7	245.4	7.28	57	23.8
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	4.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	8	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	7	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	5.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Emerald Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	9	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	9	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	7.5	7.15	76.50	171.6	6.28	62	25

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Reference site	7/6/2010	Spotfin Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Spotfin Shiner	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Yellow Perch	5.5	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Yellow Perch	6	7.15	76.50	171.6	6.28	62	25
Reference site	7/6/2010	Log Perch Darter	10	7.15	76.50	171.6	6.28	62	25
Landfill site	7/6/2010	Lg. Mouth Bass	3.5	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Lg. Mouth Bass	4	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Lg. Mouth Bass	4	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Lg. Mouth Bass	4	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Yellow Perch	5	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Emerald Shiner	5	6.97	60.00	198.6	5.03	31	27.8
Landfill site	7/6/2010	Emerald Shiner	5	6.97	60.00	198.6	5.03	31	27.8
Westinghouse Site	7/6/2010	No Fish	na	7.1	77.20	178.9	6.12	59	26.2
Residential site	7/6/2010	Emerald Shiner	6	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	5.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	9	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	7	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	8.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	8.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	6.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	7	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	6.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	5.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	4.5	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Emerald Shiner	6	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Spotfin Shiner	7	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Spotfin Shiner	7	7.36	88.60	185.9	7.17	43	26.2
Residential site	7/6/2010	Greenside Darter	5.5	7.36	88.60	185.9	7.17	43	26.2
Industrial Site	7/6/2010	Pumpkin Seed	13	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	13	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	14	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	13	7.5	88.60	218.5	7.13	68	26.6

Site	Sampling Date	Fish Species	size (cm)	DO (mg/L)	DO % Sat	Sp Cond (uS)	pH	depth (cm)	Temp (˚C)
Industrial Site	7/6/2010	Pumpkin Seed	14	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	14	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	15	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	12	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	15	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	13	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	12	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	13.5	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	13	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	12.5	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	12.5	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	9	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	7	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Pumpkin Seed	15	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Bluegill Sunfish	17	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Bluegill Sunfish	17	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Lg. Mouth Bass	16	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Lg. Mouth Bass	7	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Lg. Mouth Bass	4.5	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Log Perch Darter	10	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Log Perch Darter	10	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Log Perch Darter	10	7.5	88.60	218.5	7.13	68	26.6
Industrial Site	7/6/2010	Log Perch Darter	11	7.5	88.60	218.5	7.13	68	26.6