A Study of the Watershed Management in the Headwaters of the Hocking River: Environmental Communication in the City

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This thesis titled

A Study of the Watershed Management in the Headwaters of the Hocking River:

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by

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Abstract

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A Study of the Watershed Management in the Headwaters of the Hocking River: Environmental Communication in the City.

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Urban stormwater runoff has become of increasing concern as urban sprawl has increased over decades. With more impervious surfaces, stormwater quickly passes into freshwater ecosystems with little to no water percolating into the soil. Even if there are not impervious surfaces, stormwater may pass over agricultural lands where nitrogen and phosphorus are easily available to flow into aquatic environments. Management plans are now using different strategies to filter out sediment and nutrients before they enter lotic or large lentic ecosystems. These small ponds or constructed wetlands have larger pieces of sediment settle before they have an opportunity to flow into a larger water body. While this has shown to be a successful and useful tool to filter out materials, horizontal (lateral) movement of water during flood events has become a concern. Species in a wetland can migrate in and out of the wetland into a lentic or lotic ecosystem, returning for refuge and breeding habits. If the wetland and larger water body become cut off they develop their own line of succession. The purpose of this study is to understand and characterize the water quality between an urban stormwater wetland and the headwaters of the Hocking River. Evaluate differences of biotic assemblages in the two water bodies and present information to the neighboring AHA! A Hands-On Adventure A Children's Museum. These goals are done by conducting: fish, invertebrate, crayfish and field parameter tests.

Dedication

This thesis is dedicated to my friends and family.

Acknowledgments

I would like to acknowledge my thesis committee Dr. Natalie Kruse Daniels, Dr. Nancy Stevens, and Dr. Kelley Johnson for their expertise and patience, providing the tools, knowledge, and encouragement to complete this thesis. Thank you to the Stream and Wetland foundation for funding this project, to the AHA! A Hands-on Adventure for partnering with us, and to Jen Bowman and Nicole Kirchner for working alongside me the last two years. Thank you to Amy Mackey and Nora Sullivan who helped me grow in the field, sampling for fish and macroinvertebrate; to Dr. John Grimwade for his expertise and working alongside me on designing material for the children's museum.

This research was made possible with the community members and students who went into the field with me and gave me external support: Annika Gurrola, Nikki Salas, Marina Baldissera Pacchetti, Junia Anindya, TJ Vanek, Rebekkah Gresh-Simkovich, Andreana Madera-Martorell, Jake South, Alexandra Grbcich, Katie Schwendeman, Citlali Elena, Justin Jordan, John Timmons and James Magnificent LampPost Seraph Cephalopod Petrichor Medusa Lullaby Beauty Babayagha Tuesday Ari McGee-Moore.

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Chapter 1: Introduction

1.1 Project Goals

This study aims to achieve three major goals. First, this study will characterize the water quality in the stormwater wetland and the headwaters of the Hocking River. Second, this study will evaluate the differences between biotic assemblages in the stormwater wetland and the headwaters. These two goals will be done through a series of fish sampling, invertebrate sampling, and chemical field sampling. Third, this study will present usable information that the AHA! A Hands-On Adventure A Children's Museum can implement. To do this, information and methods have been done in a way that the museum can replicate or create educational materials from found results.

1.2 Museum Education

Museums have been a strong advocate for education outside of a school institution. Traditionally, museums have been heavy in text, curated by one individual who is a professional in their field. In more recent years, museums have gained interest in creating learning opportunities for a variety of visitors (Dube, 1998). In the United States, museums have become more interactive then they were traditionally, such as interactive educational activities leaning toward an environmental oral interpretation approach (Serrell, 1996).

Many writings on museum interpretation mention Freeman Tilden, the author of Interpreting Our Heritage, printed in 1957. While this is an old print, it creates the six foundational principles for interpretation. First, any interpretation that does not connect an object being displayed to a viewer's personal experience will be sterile. Second, information alone is not interpretation, as interpretation is perceptions based on information and always holds information itself. Third, interpretation is a resource combining many disciplines to create an educational opportunity. Fourth, interpretation's goal is not to instruct but rather cause provocation. Fifth, interpretation is meant to present a whole not parts, addressing the viewer's self. Sixth, interpretation addressing children should not hold less information being presented to adults, but be shown differently (Tilden, 1957). Museums strive to educate their visitors and give them stories (Serrell, 1996).

While creating exhibits, it is important that a creator considers universal design. Universal design is a design that can be used for all people in the best possible way without having to alter the design for different individual's needs ("What Does Universal Design Look Like?," 2011). To say simply, universal design should make any information accessible. Those creating interpretations for the public should have accommodations aligned with the Americans with Disabilities Act (ADA) and consider accommodations outside of this act. Including braille, tactile maps, and audio versions of information allows more people to experience, enjoy and take in information being presented ("What Does Universal Design Look Like?," 2011).

1.3 River Continuum Concept

Headwater ecosystems are defined as streams that flow continuously year-round excluding drought periods (Fritz et al., 2008). Often times headwater streams are made of cobble stone floor beds and are near wetlands. These streams make up more than 70% of the United States stream channel lengths (Hill et al., 2014; Lowe & Likens, 2005;

Meyer et al., 2003) and are often the habitat various fish species migrate to spawn in (Meyer et al., 2003).

River ecosystems have many naturally occurring ecosystem services including: flood control, ground water recharge, biological refuges for downstream water body species, and nutrient cycling (Lowe & Likens, 2005; Meyer et al., 2003). This suggests that positive or negative impacts in headwaters have the potential for widespread consequences throughout a watershed. These streams are the first section of the Stream Continuum Concept (RCC) that explains how larger downstream areas are dependent on chemical and biological processes upstream (Vannote et al., 1980).

RCC was first mentioned in a journal by Robin L. Vannote et. al. 1980. The concept is based upon the variable of stream size and the impact it has on lotic communities within various river sections: headwaters, midsized streams, and large rivers (Vannote et al., 1980). In upstream headwaters, riparian vegetation is important because it produces shade and organic materials for aquatic organism; however, the importance of riparian corridors varies upon the depth and turbidity of the lotic system (Vannote et al., 1980). As a river or stream increases in size, the importance of organic inputs decreases and instead begins to rely on primary production from the waters upstream (Ebersole et al., 2003; Vannote et al., 1980).

In 2015, Tornwall et. al., further reviewed this concept by conducting a literature review of papers researching aquatic biodiversity between the years of 1981 and 2014. 326 papers were reviewed and found that scholars primarily looked at how local habitat shows one of the highest impacts to stream biodiversity (Tornwall et al., 2015). Out of

326 papers, 61% of streams were impacted by natural drivers and 31% were impacted by anthropogenic drivers (Tornwall et al., 2015).

1.4 River Floodplain Movement and Temperature

Projections show that water temperatures will increase in the United States (van Vliet et al., 2012). Discharge and water temperature in a river directly affects the water quality, distribution and growth rate of organisms living in freshwater ecosystems (van Vliet et al., 2012). Along with altering growth rate, higher temperatures can alter species composition in both benthic macroinvertebrates and fish populations (Burgmer et al., 2007; Collas et al., 2019; Hogg et al., 1995; Pollock et al., 2007). When freshwater temperatures become too high, many species have die offs (Collas et al., 2019; Kurylyk et al., 2015). The Upper Incipient Lethal Temperature (UILT) in fish averages at about 30 ºC (Yoder & Emery, 2003). In Ohio, green sunfish have one of the highest UILT and are very “tolerant” (Halliwell et al., 1999; Jester et al., 1992; Karr et al., 1986). Often times, introduced species have higher fish tolerances than most native fish, facilitating the spread of introduced species (Collas et al., 2019). Invertebrates within the Ephemeroptera, Plecoptera and Trichoptera (EPT) species are some of the most sensitive species (Burgmer et al., 2007; Chang et al., 2013).

Increased water connectivity, water depth and surrounding foliage can help reduce water temperature. Discharge or runoff can introduce cooler water (Collas et al., 2019; Kurylyk et al., 2015) but it can also introduce pollutants if it comes from an urban or agricultural environment (Anim et al., 2019; Peng et al., 2018; Pullanikkatil et al., 2015; Taylor et al., 2005). Deeper water and shaded areas reduce water temperature and the diurnal temperature variation within a waterbody (Engel & Fischer, 2017). These cooler waters can serve as a refuge for organisms and allow them to thermoregulate (Collas et al., 2019; Ebersole et al., 2003). The biodiversity in the floodplains relies on healthy foliage and fauna to maintain a healthy ecosystem with cooler water temperatures (Stoffels et al., 2014).

Floodplain wetlands which can act as a refuge often times support high biodiversity (Stoffels et al., 2014; Thomaz et al., 2007). These areas do not only rely on upstream processing of nutrients but are also often impacted by lateral or horizontal movements of nutrients and sediment (Elosegi et al., 2010; Junk et al., 1989). The efficiency of a floodplain wetland and its lateral movement depends on the hydraulic characteristics in the local region (Anim et al., 2019; Kurylyk et al., 2015). These characteristics (e.g. magnitude or rate of change) can often change depending on the surrounding surface type and vegetation.

A floodplain can have similar biological species but population numbers can vary when species are momentarily stuck in a disconnected body of water (Thomaz et al., 2007). When species are trapped in one water body for an extended period of time there is potential for varying succession dynamics affecting the biological communities (Thomaz et al., 2007). With more stream modifications, floodplain connectivity can be threatened due to the loss of hydrologic connectivity (Stoffels et al., 2014).

1.5 Land Use Runoff

Freshwater lentic and lotic bodies are replenished with water from higher elevations in their watershed. Water typically percolates into the soils, feeding plant life and creating moist topsoil. However, the human population is increasing causing cases of urban sprawl, clearing of natural vegetation, and an increase in surface runoff pollutants (Pullanikkatil et al., 2015; Sorensen et al., 1977). Cities have the highest amount of un-natural impervious surfaces (Haase, 2009). Urban land use change causes higher volumes of surface runoff and causes higher peak flood discharges within a shorter amounts of time (Peng et al., 2018). Animal and crop agriculture intensification using higher levels of fertilization and pesticides result in increased nutrient loads within aquatic ecosystems (Jordan et al., 2003; Matamoros et al., 2012). This can cause high levels of nitrogen and phosphorus that increases gross primary productivity (GPP) contributing to eutrophication in lentic bodies of water (Howarth et al., 2000; Matamoros et al., 2012; Sorensen et al., 1977; Taylor et al., 2005). Eutrophication causes anoxic and hypoxic water causing harmful effects on the animals living in them (Howarth et al., 2000; Pollock et al., 2007).

Water quality related to land use change has different management styles across the globe (Pullanikkatil et al., 2015). Three main styles of water runoff management are Low Impact Development (LID) (Peng et al., 2018), Stormwater Control Measures (SCMs) (Anim et al., 2019) and general strategies for sediment filtration (Taylor et al., 2005). LID has seven different scenarios to reduce flooding in both small and long-term rain events. This style of management uses a variety of permeable surfaces as the best strategy to reduce flood events. Recently the United States has changed management of water discharge and water quality control to the LID management format (Peng et al., 2018). SCMs are meant to mitigate the impact of stormwater runoff and maintain natural water levels; the main objectives of this management plan are to reduce the amount of stormwater runoff, restore lost percolation, and recover the predevelopment runoff response condition (Anim et al., 2019). An example of SCMs is a bio-retention system or a constructed wetland to mitigate the runoff from reaching a stream (Anim et al., 2019). Sediment filtration is commonly conducted with a “treatment train” approach where wetlands or heavily vegetated areas encourage coarse grain sediments to settle or be removed as a downstream region promotes biofilm growth to dissolve pollutants and finer particulates (Taylor et al., 2005).

SCM management often recommends the development of stormwater catchment basins or wetlands (Anim et al., 2019; Grung et al., 2016; Ivanovsky et al., 2018). These lentic bodies help prevent flooding (Ivanovsky et al., 2018) and can help reduce the effect of run off from affecting river environments (Grung et al., 2016). While these water bodies can be beneficial for river species many of the species living within the wetlands can suffer from environmental degradation (Chaichana et al., 2011).

An increased volume of nutrients and chemicals that run off from urban or agricultural environments and the acts of deforestation, ecosystem services begin to decline (Pullanikkatil et al., 2016). Stormwater wetlands that catch this runoff can contain various materials including: suspended particulate (SPM), trace metals, polycyclic aromatic hydrocarbons (PAHs), nitrogen and phosphorus, caffeine, bacteria, and many other pollutants (Grung et al., 2016; Ivanovsky et al., 2018; Matamoros et al., 2012). These particulates have the potential of having harmful effects on the biological species living in an ecosystem and can reduce the biodiversity that is present (Burgmer et al., 2007; Grung et al., 2016; Ivanovsky et al., 2018).

1.6 Site Characterization

The AHA! A Hands-On Adventure, A Children's Museum where this study took place, owns 12 acres of land consisting of wooded land, field, and an urban wetland body. The children's museum is located at 1708 River Valley Circle S, Lancaster, Ohio 43130 behind the main mall section of the River Valley Mall. These habitats create a small patch of riparian buffer to mitigate the mall surface run off from entering the headwaters of the stream quickly. Next to these features, behind the museum, the city has a bike path running through a wetland that acts as a stormwater wetland or run-off catchment basin before water can flow in the headwaters of the Hocking River. Other than the confluence tunnels connecting the wetland and river together, rare high-volume flooding events can occur. During these events the two water bodies can overflow and connect.

This subwatershed of the Hocking River has been studied four times since 1980 and has shown large changes between each sampling event. In 1982 the Hocking River at River Mile (RM) 95.2 received a Fish Index of Biotic Integrity (IBI) score of 27; at RM 90.7 the fish IBI score was 17 (Ohio EPA, 1997). The Qualitative Habitat Evaluation Index (QHEI) at RM 95.2 and 92.0 was 46.0 and 48.0, respectively (Ohio EPA, 1997). In 1990, the Hocking River fish IBI scores at RM 95.2 and RM 90.8 were 35 and 28, respectively (Ohio EPA, 1997). In 1990 the QHEI at RM 95.2 and RM 90.8 scored a 66.0 and 44.0, respectively. In 1995, The Hocking River IBI score at RM 95.2 and RM 90.8

were 40 and 33, respectively (Ohio EPA, 1997). During the 1995 sampling event the QHEI scores at RM 95.2 and 90.8 were 85.0 and 41.5, respectively. Finally, in the most recent sampling event in 2004, the Hocking River fish IBI score at RM 96.8 and 91.9 were 42 and 32, respectively (Ohio EPA, 2009a). During the 2004 sampling event, the Ohio EPA found that at RM 96.8 QHEI score was 72.5 and RM 91.9 scored as 52 out of 100. Each time the Hocking River has been sampled improvement has been shown.

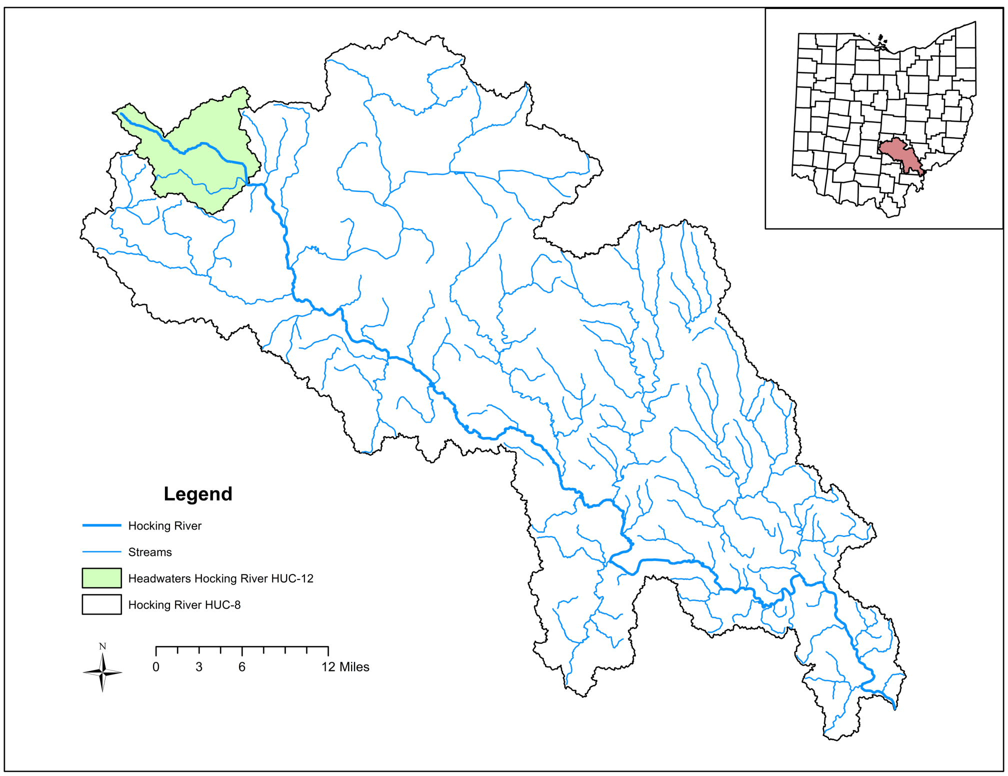
The stormwater wetland was originally a flood storage basin constructed in 1986 by Glimcher Reality (*Hocking River Stream Restoration & Wetland | Lancaster, OH - Official Website*, n.d.). After maintenance was neglected, sedimentation built up and the basin was altered to be a wetland in 2008 by placing inlet structures. There has not been any publicly shown water quality data recorded in this wetland. It does have trail signage showing its history and in 2011 nesting boxes were installed (*Hocking River Stream Restoration & Wetland | Lancaster, OH - Official Website*, n.d.). Since there has not been data collected in recent years, the AHA! Children's Museum wants to broaden the understanding of these ecosystems to educate their visitors.

1.6.1 Subwatershed Background

This study collected information on the headwaters of the Hocking River at the HUC-10 assessment unit, 05030204-010-010 (Figure 1). The Hocking River is 102 miles long (Ohio EPA, 2009a) beginning in Central Ohio at Fairfield County and draining into the Ohio River in Southeastern Ohio within Athens County (*Hocking Conservancy District | Hocking River | Watershed*, 2012). The Hocking River watershed drains an average total amount of 1,196 square miles of water through the seven-county region it extends (Ohio EPA, 2009a). Overall, the Hocking River Watershed is approximately 62% forested. The upper portion of this watershed has the most concentrated section of agricultural lands representing 27% of the total land use (Ohio EPA, 2009b).

Figure 1

Hocking River Watershed Map



Note. Hocking River watershed map made by Jennie Brancho.

The drainage area of the upstream site is 0.9 mi^2 and the drainage area of the downstream site is 35.2 mi^2 (*StreamStats*, n.d.). The average precipitation in the sampling sites is 38.8 inches annually (*StreamStats*, n.d.). The Hocking River is characterized by three ecoregions the Erie/Ontario Lake Plain (EOLP), Eastern Corn Belt Plains (ECBP), and the Western Allegheny Plateau (WAP), where most of the watershed is found (Ohio EPA, 1991). The headwaters of the Hocking River this study is looking at is located in the ECBP region. The ECBP region is characterized by flat terrain and have soils derived from glacial till materials with poor soil drainage (Ohio EPA, 1991).

1.6.2 Land Use in the Headwaters of the Hocking River

The City of Lancaster, Ohio is the largest urban area in the Hocking River Watershed (Ohio EPA, 2009a). The northern end of this subwatershed is primarily row crop agriculture with varying sizes of forest and pastures (Ohio EPA, 2009b).

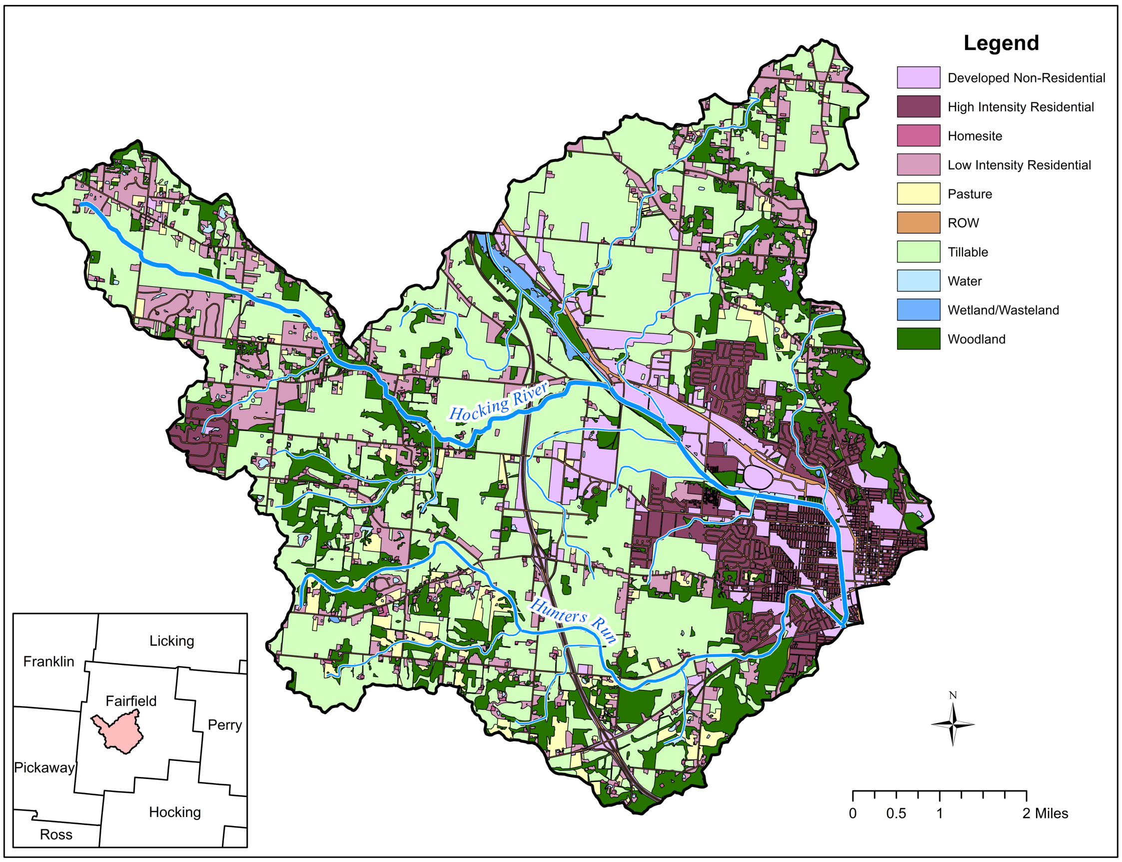
Studies show that changes in water quality are strongly related to changes in land use (Pullanikkatil et al., 2015). It is important for the headwaters of the Hocking River to be studied because Lancaster is the first of three high land use areas along the Hocking River watershed. Currently it is the highest urban land use area in the headwater watershed (Ohio EPA, 2009b) and plans for more urban development after the construction of U.S. Route 33 Bypass (*Fairfield County Comprehensive Land Use Plan*, 2018).

In the 2018 Fairfield County Land-Use Plan, the city stresses the importance of preserving farmland and growth in the city. In this plan, the area where this study will be done, behind the River Valley Mall, is in the commercial land-use area, growth area, Lancaster wellhead protected area, and is in the area with the highest pollution potential. Shown in Figure 2, the Headwaters of the Hocking River are 19% Residential, 2.9 % Commercial/Industrial, 73.7% Agriculture, 4.3% Public, and 0.1% Utilities (*Fairfield*

County Comprehensive Land Use Plan, 2018). The AHA! Children's Museum is located right next to the only woodland area found in the developed non-residential area.

Figure 2

Land Use Map of Headwaters of the Hocking River



Note. Land use map by Jennie Brancho.

1.6.3 Water Quality in the Hocking River Headwaters

The Ohio EPA most recently sampled the Headwaters of the Hocking River in 2004. This study replicated measurements at the Ohio EPA sites at RM 91.9/92.2 and

RM 90.8/90.7. This study will also be referencing the Ohio EPA RM site upstream of these sites, RM 96.8. RM 96.8 is designated as a warm water habitat (WWH), which is the baseline regulatory requirements in line with Clean Air Act "fishable goal" expectations (OhioEPA 2004). WWH are similar to least impacted reference conditions having normal assemblages of invertebrates and fish. Most of 91.9 is a modified warm water habitat (MWH) meaning that its requirements are less restrictive from dissolved oxygen and ammonia, sometimes resulting in less restrictive wastewater treatment requirements (OhioEPA 2004). The fish species and macro-invertebrates that live in MWH can be mildly tolerant species and are very similar to WWH, but with modification that has irretrievable recovery conditions.

The Ohio EPA has done Total Maximum Daily Load (TMDL) reports on the headwaters of the Hocking River in 1981, 1990, and 2004 (OhioEPA 2009). In the 1991 TMDL report the EPA found that the Hocking River began as WWH and after RM 92.0 biological quality declined as it flowed through the city of Lancaster, OH (OhioEPA 1991).

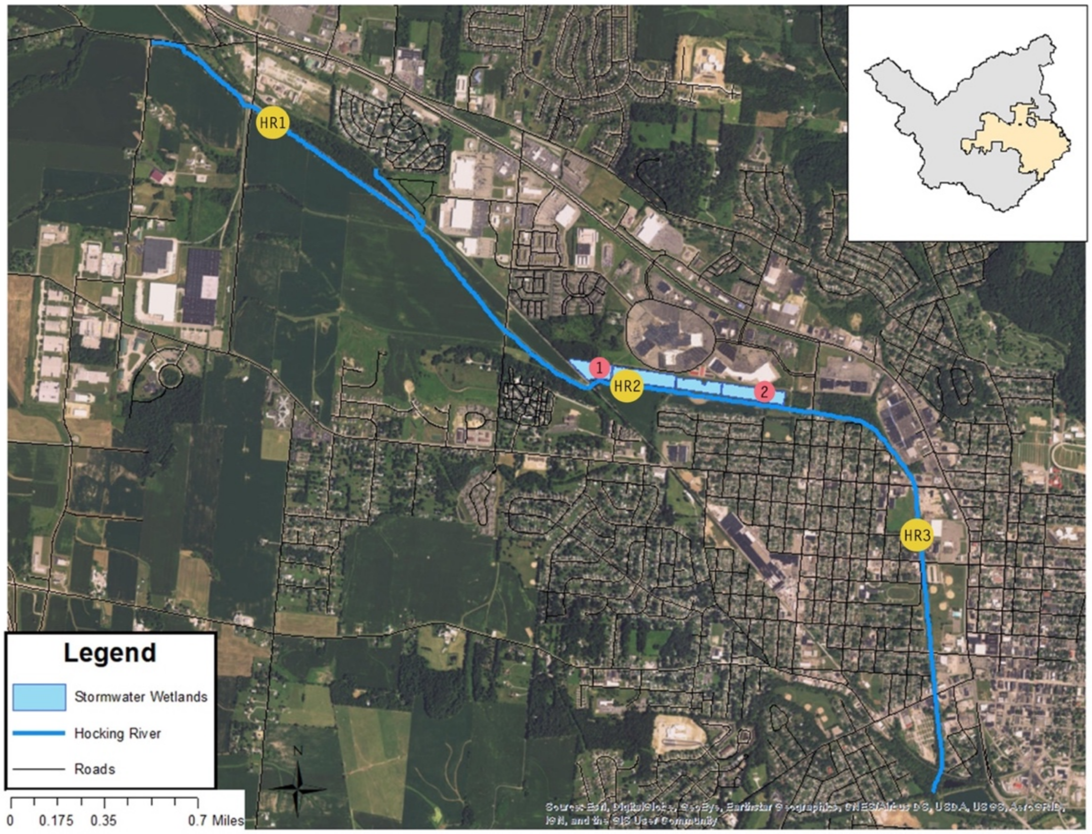
Chapter 2: Methods

Study Site

This study sampled five locations; three sites in the headwaters of the Hocking River and two sites in the adjacent stormwater wetland that is behind the AHA! Children's Museum. The parameters that were measured within these sites include: fish sampling, macroinvertebrate sampling, and water chemistry sampling. Sites studied will be referred to as HR1, HR2, HR3, SW1 and SW2 (Figure 3). HR sites refer to the Hocking River, HR1 is at river mile 93.6, HR2 is at river mile 92.6 and HR3 is at river mile 91. HR2 and HR3 will be compared with Ohio EPA sampled sites at RM 91.9/92.2 and RM 90.8/90.7, respectively. SW sites refer to the stormwater wetland, SW1 is next to the AHA! Children's Museum and SW2 is behind the Target at the Lancaster River Valley Mall.

Figure 3

Sampling Locations



Note. There are five sampling locations in Lancaster, Oh. The three yellow points indicate HR1, HR2, and HR3. The two red points indicate SW1 and SW2 sampling sites.

Sampling Methods and Frequency

a. *Habitat quality* - Before assessing the long-term chemical processes and the biological trends over time, the habitat quality of the Hocking River and the wetland were assessed. Information from the Ohio Environmental Protection Agency (Ohio EPA) indicates that there is a lack of riparian corridors surrounding the upper Hocking River.

Information from the Fairfield County Comprehensive Land Use Plan shows that the area surrounding the River Valley Mall in Lancaster, Ohio is in an area with frequent flooding and with a high threat of pollutant run-off.

To monitor the habitat quality in the Hocking River an Ohio EPA Qualitative Habitat Evaluation Index (QHEI) was conducted once during within the indicated period of June 15th and September 30th at each site (OhioEPA 2006). This was done by Amy Mackey, certification 00146, and Moira Snuffer. This evaluation is composed of six principal metrics: Substrate, Instream Cover, Channel Morphology, Bank Erosion and Riparian Zone, Pool/ Glide and Riffle/ Run Quality, and Gradient. Each of these metrics have different subcategories that are given a number of points based on how ideal they are for an ecosystem. When all of these metrics have beened scored and collected the scores will be added together to create a QHEI site score out of 100 points.

To monitor the habitat quality in the wetland, the Ohio Rapid Assessment Method for Wetlands (ORAM) (OhioEPA 2001) was conducted once per wetland site. This assessment was done by Moira Snuffer, MS. This assessment scores a wetland based on 8 sections: wetland area, upland buffers and surrounding land use, hydrology, habitat alteration and development, special wetlands, and plant communities, interspersion, microtopography. It then goes into a narrative rating system observing any critical habitat, endangered species, breeding areas, and neighboring terrestrial species type. To find the results of the ORAM, quantiative scores were added in a wetland categorization worksheet and could have a maximum score of 100.

To measure the relationship between the HR sites and the SW sites this project conducted tests quantifying the river and wetland water quality. Measurements and records of dissolved oxygen (DO), total suspended solids (TSS), total dissolved solids (DS), turbidity (NTU), pH, temperature (^{O}C), conductivity (µS/cm), oxygen reduction potential (ORP, mV) and water level were taken every other week between June 21st, 2019 and November 19th, 2019. Biweekly samples show chemical dynamics during two seasonal periods: Summer and Fall.

b. *Water Chemistry* - Samples were collected as an analytical batch at each sampling site in three 300mL HDPE bottles. The water was first collected from a metal bucket that had been rinsed in the water body three times, then water from the bucket was poured into the bottles. Collected water was transported to Ohio University Research and Technology Center where filtering commenced.

To filter the water, 0.45 µm clean glass filters were dried, weighed, recorded, and then placed onto aluminum trays. Water samples were shaken to suspend sediment evenly within the 300mL containers; samples then were poured into 500 mL containers where a vacuum filtration system pulled the water through the filters. After the water had completely gone through the filters, they were placed back into their original aluminum trays and put into a 104˚C oven for one hour to dry completely.

After drying completely, filters were moved and placed into a desiccator. They cooled to room temperature before being reweighed. TSS was determined by subtracting the pre-filtered weight from the post-filtered weight, as seen in Equation 1.

$$\text{Equation 1: } \text{TSS}\left(\frac{\text{mg}}{\text{L}}\right)=\frac{\text{final weight-initial weight}}{\text{volume of sample filtered}}$$

DO, ORP, pH, TDS, temperature, conductivity, and turbidity were measured on-site. These parameters were done at the same time to prevent any metals from oxidizing in sampling bottles tampering with the pH and DO readings. A Myron Ultrameter 6p measured the ORP, pH, temperature, TDS, and conductivity; while a YSI optical dissolved oxygen probe was used to measure DO. A secchi disk transparency tube was used to measure turbidity. Transparency tube data is recorded in centimeters (cm) so data recorded was converted to a standard Nephelometric Turbidity Units (NTUs) using the Turbidity Tube Conversion Chart supplied by Utah Water Watch (Utah State University Extension, 2016).

The Myron Ultrameter 6p was calibrated with a three-point pH calibration solution and a two-point conductivity and TDS calibration each sampling day. The sampling wells were triple rinsed at each site, then data was collected and recorded. To measure the turbidity a one-meter secchi disc/tube from Water Monitoring Equipment and Supply manufacturing, so the museum would be able to replicate measurements themselves at a lower cost than by using other turbidity readers. This tube was submerged into the water of the sampling site to collect water. An individual looked into the tube and released water until the checkered disc at the bottom of the tube became visible. The same person measured turbidity at every site on sampling periods to reduce subjective readings. The number shown on the side, where the meniscus is located, was then recorded. DO and temperature were measured using a YSI optical dissolved oxygen probe when placed into the water. When readings became stable for approximately 30 seconds, the DO and temperature were recorded.

c. Stage and Discharge - River flow and elevation were checked prior to sampling after information was found from the USGS Hocking River at Union St in Enterprise OH. A water level meter, a Van Essen CTD diver and baro, were installed in the Hocking River at HR2 to monitor the water level.

d. Fish Sampling - Fish populations were monitored to develop an understanding of the biotic assemblages and better replicate the Ohio EPA sampling events. In the HR sites, this project found the Index of Biotic Integrity (IBI) and Modified Index of Well Being (Miwb). Collection for an IBI score in the HR sites will follow the practices done by the Ohio EPA Standards (Ohio EPA, 2015). Fish were conduct by a team led by Amy Mackey who has a level three Fish Community Biology – Headwater and Wading Only certification under the Division of Surface Water Credible Data Program, Qualified Data Collector number 00146. The dates of sampling took place between mid-June and early October, the dates when river fish are under the least amount of stress (Ohio EPA, 2015).

In HR sites, fish were sampled using a long line electrofisher. This is shown to be best sampling method for rivers consisting of both riffles and runs (Ohio EPA, 2015). A minimum of three individuals manned the long line. One with the electrified net and two with sweep nets capturing fish that are stunned. Fish sampling was done for 200 meters, 100 meters upstream and 100 meters downstream from HR1, HR2, and HR3 points. The total time invested at each site was 45 – 60 minutes long.

Every individual collected was weighed, counted and recorded. Species at each site were recorded on their own Ohio Department of Natural Resources (ODNR) species diversity form. This form requires the date, time, distance, sampling type, stream name, latitude and longitude location, drainage amount, basin name and names of the individuals capturing species. Sampling was at each site at least once between June and August.

In the wetland sites, a long-line electrofishing unit had three individuals sampling. One operating the electrified net while two others kicked up sediment and captured any fish with sweep nets. This was done for a minimum of 45 minutes in SW1. SW2 was too dangerous for sampling due to high levels of siltation. Species at SW1 were identified and counted at each site and recorded on a ODNR species diversity form. This sampling was done between the recommended June and October sampling period. Fish were sampled in the Hocking River on August 2nd and September 27th. Fish sampling took place on June 17th within the sampled wetland.

Invertebrates - To better understand the water quality and biotic assemblages in the two water bodies, macroinvertebrate species were sampled as bio-indicators. Macroinvertebrates were sampled at each site HR site using the Macroinvertebrate Aggregated Index for Streams (MAIS) standard procedures (Johnson, 2007). This was done between June 15th and September 30^{h}. Samples of macroinvertebrates were taken in the Hocking River were taken on August 8th, September 3, and September 30th. Samples of macroinvertebrates were taken in the wetland on

September 16th. Sampling is required to be done during low flow conditions when there has not been rain within four days of intended sampling.

A team of three collected specimens at locations with riffles and pools for a distance of 150 meters. One person used a dip net in varying habitats to proportionally represent the habitat types available, while two people used a kick net in riffles. One person will hold the net while the other places rocks on the bottom of the net to reduce any chance of macroinvertebrates going under the net. The person who secured the rocks on the bottom of the net will then kick about a square meter of sediment vigorously into the net. The kicker then helped the net holder transport the net onto a shower curtain.

The two individuals picked through the net looking for any macroinvertebrates that were captured. The shower curtain was also be inspected to ensure no macroinvertebrates have moved through the net and onto the curtain. All macroinvertebrates were preserved in 70% ethyl alcohol and identified to family level.

SW sites were sampled using a modified Hess bucket sampler method. These sites were sampled within the standard June 15th and September 30th dates. The Hess sampler is a bottomless 26 cm diameter bucket and is sampled with a small 250 micron dip-net. To collect macroinvertebrates the Hess bucket was placed into the wetland substrate and a dip-net was dipped in the bucket 20 times collecting invertebrates from the sediment and the water column. The bucket was placed in the substrate at four locations around SW1 and SW2 with 5 dips in each location. Macroinvertebrates collected were sorted from detritus in a sorting pan. Collected specimens were handled with forceps and preserved in 70% ethyl alcohol then identified to family level.

Crayfish were sampled using methods stated in Gavioli et al. (2018). In this method of sampling, 15, 40 x 25 x 25 cm, 0.3cm mesh plastic traps were set out at 7pm and taken out at 7am the next morning. These traps have two openings on each side allowing crayfish to enter. Crayfish that are caught were then weighed and measured to the nearest 0.1 mm. The primary reason for sampling crayfish in this study is to gain information and understanding for the museum's future educational materials.

Data Analysis

The results of this study were analyzed using a Kruskal-Wallis Rank sum test. The Kruskal-Wallis Rank sum test was used to analyze the species numbers between the three HR sites. The null for this test is that the number of individuals have the same distribution in the HR sites. This was done to identify if there is any difference in species richness and species abundance. Field parameters data were also be compared to the data obtained in the stormwater gage to look at overarching trends present with rain events. To see if there is a correlation between turbidity and TSSs a Spearman's rank correlation was conducted in RStudio. The Null for this test is that there is no relationship between TSSs and turbidity ($\rho = 0$).

Chapter 3: Results

3.1 Habitat Evaluation

In the Hocking River sites, the Quality Habitat Evaluation Index (QHEI) was performed on the day fish sampling took place. HR1, taken on August 2nd, had a score of 66.5 giving it a habitat categorical score of "good". HR2, taken on August 2nd, had a score of 66 giving the site a habitat categorical score of "good". HR3, taken on August 1st, had a score of 36.5 giving the site a habitat categorical score of "poor". These results show that habitat quality declines upstream to downstream.

In March 2020, both SW sites, the Ohio Rapid Assessment Method for Wetlands (ORAM) version 5.0 was conducted using images of the sites and field data. SW1, the site closest to the Children's Museum, scored a 35.5 out of 100 indicating it as a Modified Category 2 wetland. SW2, the site behind Target, scored a 20 out of 100 indicating it as a Category 1 wetland.

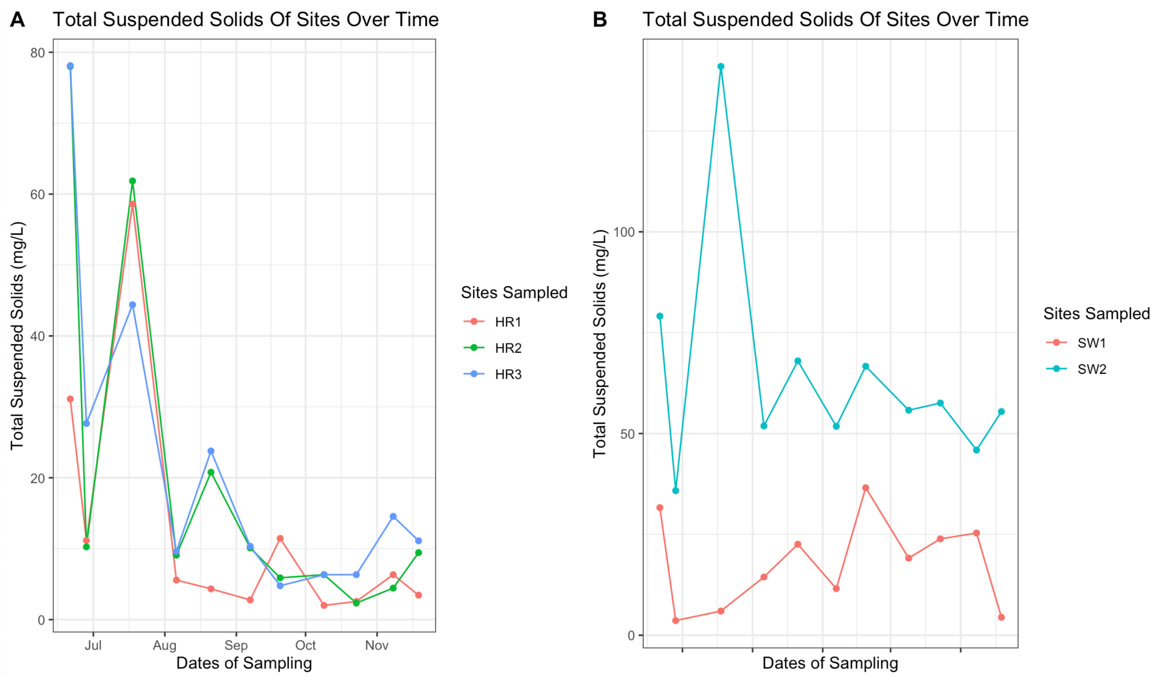
3.2 Total Suspended Solids

Total Suspended Solids (TSS) was similar within all the Hocking River (HR) sites and less with the stormwater wetland (SW) sites. TSS was higher in the Summer months of June, July and August in HR sites and lower in Fall months of September, October, and November. The summer months had more variation within the Summer period of sampling ranging from 10.3 mg/L to 20.8 mg/L while the Fall sampling period ranges at a steady lower level between 2 mg/L and 14.6 mg/L. TSS concentrations became lower and became steadier during sampling events after July 18th. The desired level of TSS in surface water is below 65 mg/L ("OAC Chapter 3745-2," 2014).

TSS in SW2 was higher than TSS in SW1 throughout the two seasons. Both SW sites followed similar trends other than mid-July and late November. TSS concentration in SW2 sites followed a similar trend with the river sites while TSS in SW1 remains low and less similar to the HR sites. During the summer sampling period TSS in SW1 ranges between 31.6 mg/L and 3.6 mg/L with a difference of 28 mg/L and SW2 ranges between 35.8 mg/L and 79.1 mg/L with a variation of 43.3 mg/L. During the fall sampling period TSS ranges in SW1 ranges between 4.4 mg/L and 25.3mg/L with a variation of 20.9 mg/L while TSS in SW2 ranges between 45.9 mg/L and 57.6 mg/L with a variation of 11.7 mg/L. SW2 has the highest concentration of TSS with 9 sampling events having TSS concentrations above 50 mg/L and the second highest concentration was HR1 and HR2 with 2 sampling events showing TSS to be above 50 mg/L. None of the other sites had any TSS concentrations above 50 mg/L.

Figure 4

Total Suspended Solids of Sites Over Time



Note. Graph A shows TSS in the Hocking River sites; graph B shows TSS in the stormwater wetland sites.

3.2 Dissolved Oxygen

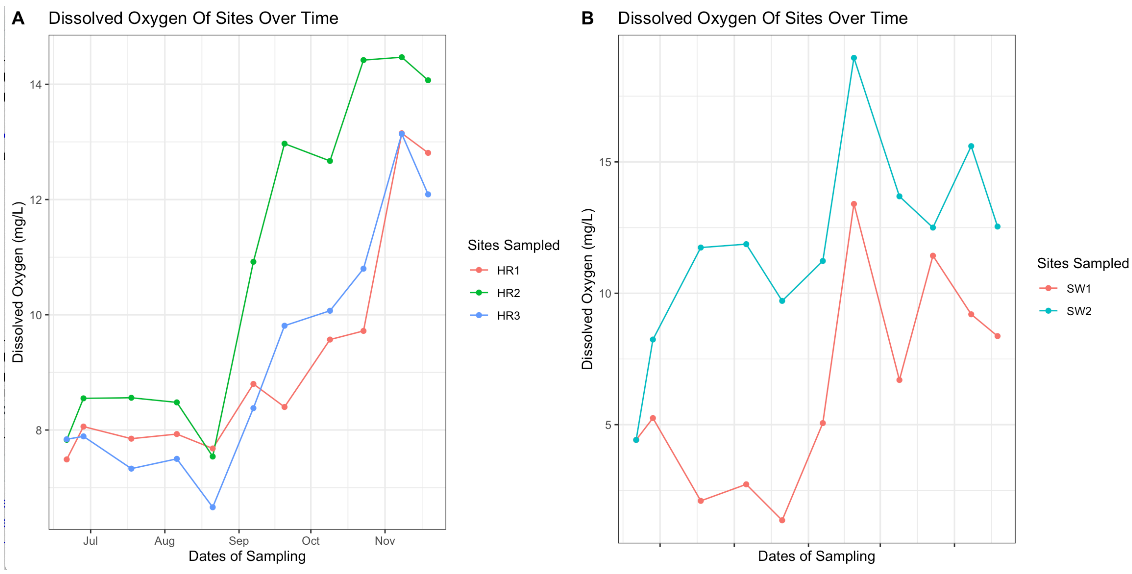
Dissolved Oxygen (DO) in the HR sites followed a similar trend throughout the two-season period though HR2 was slightly higher throughout the two-season sampling period. DO in the Summer months were lower than the fall with HR1 ranging between 7.49 and 8.06mg/L, HR2 ranging between 7.54 and 12.97 (9.20) / 8.56 (8/21) and HR3 ranging between 9.81mg/L and 6.66mg/L. HR3. DO levels steadily increased in the Fall months beginning in late-September this ranges between 8.40 and 13.15 at HR1, 12.67 and 14.47mg/L at HR2, and 10.07 and 13.14mg/L at HR3. The variation between HR1 is

4.75mg/L, the variation between HR2 is 1.80 mg/L, and the variation between HR3 is 3.07 mg/L. DO levels begin to rise at the September 9th sampling date.

DO in the SW sites were follow the opposite trend line from one-another in early summer until the August 21st sampling date, when they follow the same trend until sampling ended. In the early summer dates between June 21st and August 21st SW1 ranged between 1.36 mg/L and 5.25 mg/L with a variation of 3.89 mg/L while SW2 ranged between 4.42 mg/L and 11.74 mg/L with a variation of 7.32 mg/L. In the late summer months and Fall, SW1 ranged between 5.06 mg/L and 13.40 mg/L with a variation of 8.34 mg/L, while SW2 ranged between 11.23 mg/L and 18.96 mg/L with a variation of 7.73 mg/L.

Figure 5

Dissolved Oxygen in sites



Note. Graph A shows TDO in the Hocking River sites; graph B shows DO in the stormwater wetland sites.

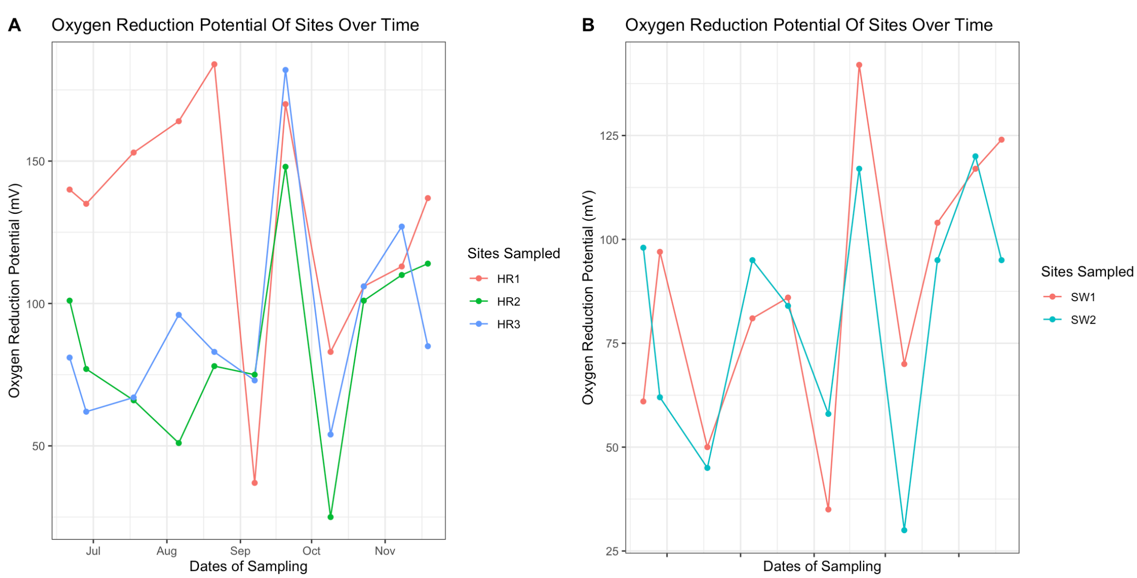
3.3 Oxygen Reduction Potential

Oxygen Reduction Potential (ORP) in HR sites during the Summer months showed variation between sites but began to follow a similar non-linear trend on the September 7th sampling event. In the Summer sampling events between June 21st and August 21st, HR1 ORP levels were high compared to HR2 and HR3 ranging between 135 mV and 184 mV. HR2 ranged between 51 mV and 101 mV and HR3 range between 62 mV and 96 mV. Within the Fall months the three river sites follow a similar trend line at different degrees.

ORP measured in the wetland sites follow a similar trend line throughout the summer and fall sampling periods. In the summer months, both of these sites range between 35mV and 98mV. In the fall months there is more variations within both of these sites ranging between 30mV and 142mV. As seen in figure 6, the average ORP in June is 79 at SW1 and is 80 mV at SW2. In July, ORP was 50 mV in SW1 and 45 in SW2. In August, ORP averaged as 83.5 mV in SW1 and 89.5 mV in SW2. In September ORP averaged at 88.5 mV in SW1 and at 87.5 mV. In October, ORP averaged at 87.0 mV in SW1 and averaged at 62.5 mV in SW2. Finally, in November, ORP averaged at 120.5 mV in SW1 and averaged at 107.5 mV in SW2.

Figure 6

Oxygen Reduction Potential



Note. Graph A shows ORP in the Hocking River sites; graph B shows ORP in the stormwater wetland sites.

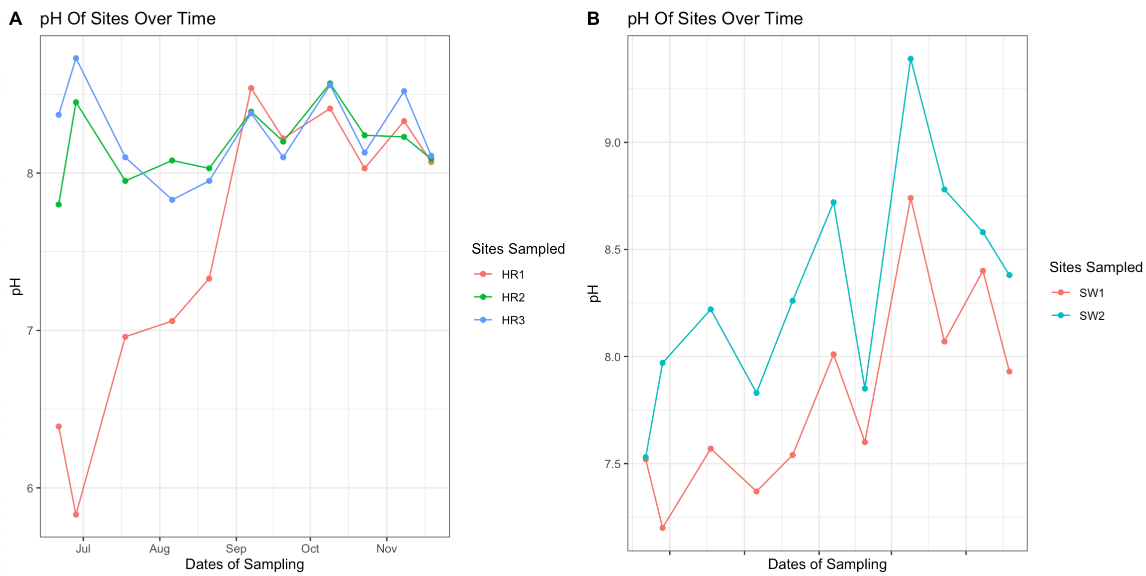
3.4 pH

pH in HR2 and HR3 were similar throughout the entire sampling period. Both sites ranged between a pH of 7.80 and 8.73. HR1 was only similar to HR 2 and HR3 during the Fall sampling period, between September 7th and November 19th. In the Summer sampling period, June 21st to August 21st, pH at HR1 was much lower than the other river sites. In June, the pH in HR1 was an average of 6.11 and then in July and August was an average of 7.12. The desired pH range for aquatic life is between 6.5 and 8.

As seen in Figure 7, pH in SW sites followed a similar trend throughout the sampling period but SW2 was slightly higher than SW1. In spring, SW1 ranged between 7.20 and 8.01 while SW2 ranged between 7.53 and 8.72. During the fall sampling period, SW1 ranged between 7.93 and 9.74 while SW2 ranged between 8.38 and 9.39. The highest date pH was sampled for both sites was on October 9th. The lowest pH was sampled on June 28th at site SW1 and was lowest on June 21st at site SW2.

Figure 7

pH



Note. Graph A shows pH in the Hocking River sites; graph B shows pH in the stormwater wetland sites.

3.5 Temperature

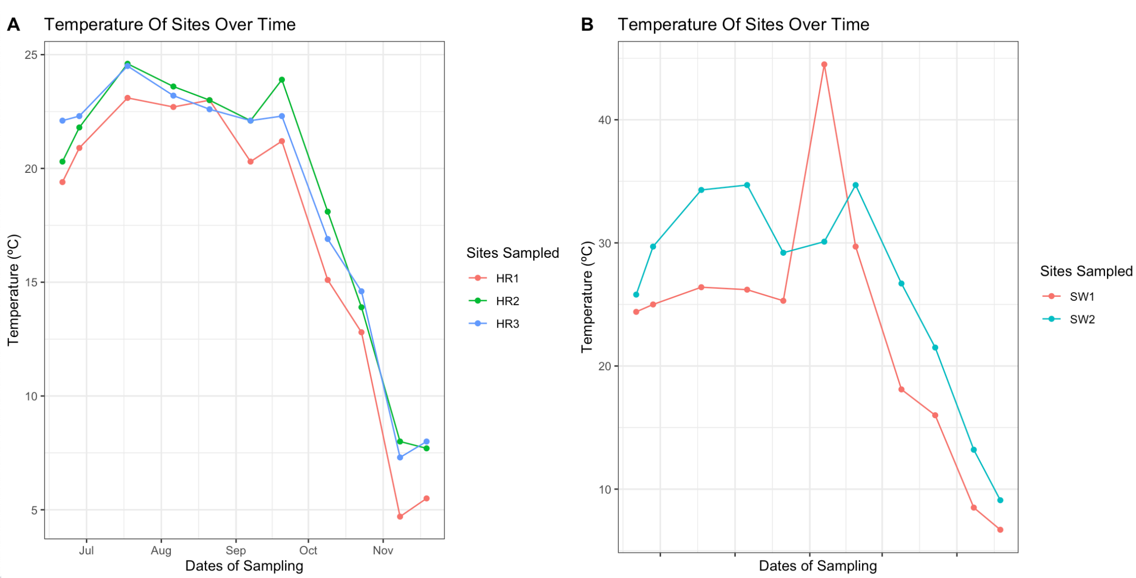
Temperature in all HR sites followed a similar trend line. In the summer months, HR sites ranged between 19.4 °C and 24.6 °C, declining in September. In all sites, the average October temperature was 15.2 °C while the average November temperature was 6.9 °C. The lowest temperature for all HR sites was sampled on November 8th. The highest temperature for all HR sites was sampled on July 18th.

Temperature in both SW sites were similar and declined over time. SW1 was consistently cooler than SW2, except on September 7th when SW1 (44.5 °C) was 14.4 °C higher than SW2 (30.1 °C). During the summer sampling period, SW2 was an average of

2.4 °C warmer than SW1. The largest difference between these two sites was 7.9 °C in July and the smallest difference (1.4°C) in June. In fall, SW sites follow the same trend as HR sites declining in temperature after September sampling. October temperatures average at 17.1°C in SW1 and at 24.1 °C in SW2. In November temperatures average at 7.6 °C in SW1 and at 11.2 °C in SW2. Between October and November, the temperature difference is 9.5 °C in SW1 and 12.9 °C in SW2. Seen in figure 8, the highest temperature recorded for SW1 was on September 7th measuring at 44.5 °C. The highest temperature for SW2 was August 6th and September 20th measuring at 34.7 °C.

Figure 8

Temperature



Note. Graph A shows temperature in the Hocking River sites; graph B shows temperature in the stormwater wetland sites.

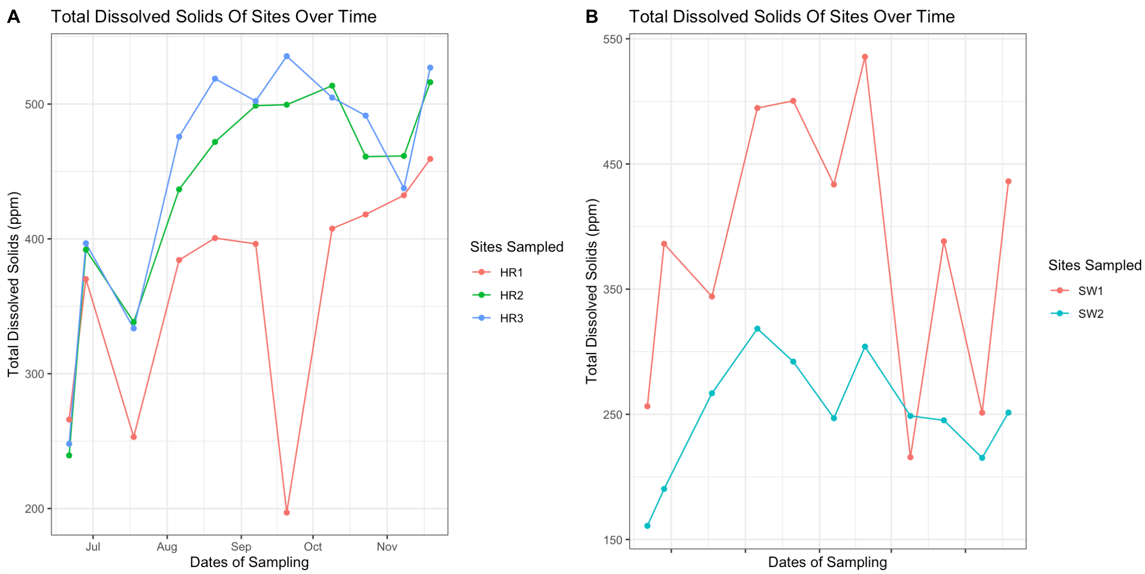
3.6 Total Dissolved Solids

Total Dissolved Solids (TDSs) in HR sites was variable. HR3 and HR2 followed a similar trend with HR3, being lower in the summer and higher in the fall. HR1 was regularly lower than the other two sites with a low spike on September 20th where it is at 197.0 ppm. The average TDSs in summer at HR1 is 323.9ppm including the September 20th event and is 345.1 ppm without the September 20th date. In summer, the average TDSs in HR2 is 410.9 ppm and in HR3 is 430.1ppm. In Fall, the average TDSs in HR1 is 429.3 ppm, in HR2 is 488.1 ppm, and in HR3 is 490.2 ppm.

In SW sites, there is little similarity between sites. SW1 has a higher level of TDSs other than on October 9th sampling date. Seen in figure 9, both SW sites TDSs increases between June and August sampling events then become irregular between September and November. The average TDSs in June is 321.3 ppm in SW1 and 175.7 ppm in SW2. In July, TDSs was 344.1 ppm in SW1 and 266.8 ppm in SW2. In August, TDSs averaged as 497.6 ppm in SW1 and 305.3 ppm in SW2. In September, TDSs averaged at 484.6 ppm in SW1 and at 275.5 ppm in SW2. In October, TDSs averaged at 302.0 ppm in SW1 and 247.0 ppm in SW2. Finally, in November, TDS averaged 343.7 ppm in SW1 and 233.3 ppm in SW2.

Figure 9

Total Dissolved Solids



Note. Graph A shows TDS in Hocking River sites; graph B shows TDS in the stormwater wetland sites.

3.7 Turbidity (NTU)

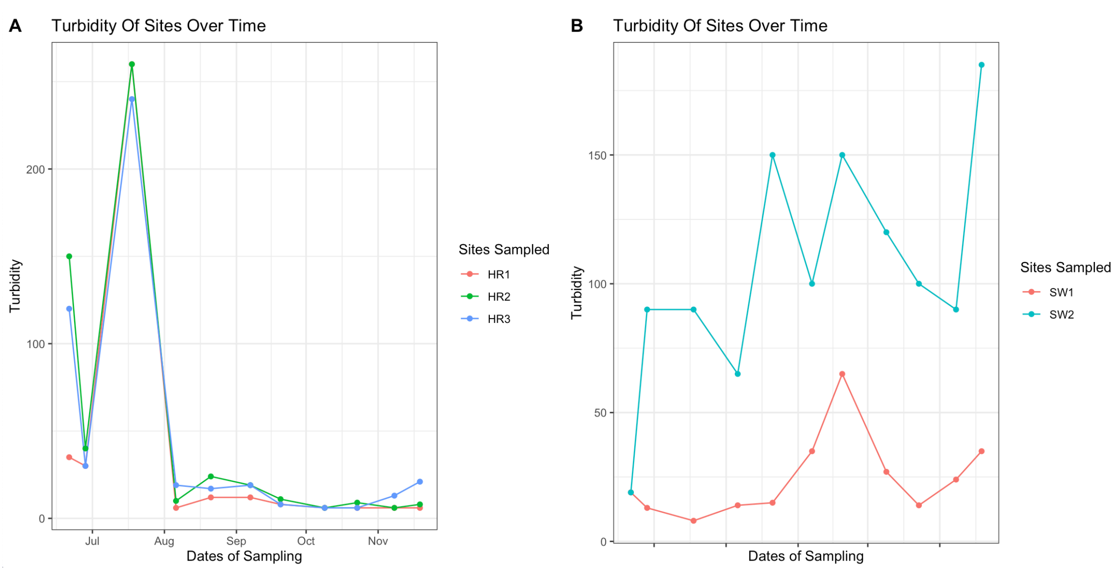
Turbidity in the HR sites are almost identical throughout the sampling period. The three sites are highest on July 18th where they all exceed the 180cm limit that the turbidity tube ended. For this study, we have given those sites an NTU above 200. Other than these abnormalities, the highest data recorded was on June 21st where HR1 is 35 NTU, HR2 is 150 NTU and HR3 is 130 NTU. Starting after August 6th, all sites remained within the range of 6 NTU and 24 NTU.

Turbidity in the SW sites are similar, but SW1 is lower than in SW2. Seen in figure 10, the highest turbidity sampled for SW1 is on September 20th and for SW2 is on

November 19th. The lowest sampling data for SW1 is July 18th while the lowest for SW2 is June 21st. To see if there is a correlation between turbidity and TSSs a Spearman's rank correlation was conducted in RStudio. The Null for this test is that there is no relationship between TSSs and turbidity (*ρ = 0).* We reject the null hypothesis and find that HR's TSSs and HR's turbidity are positively correlated. We reject the null hypothesis and find that SW1's TSSs and SW1's turbidity are positively correlated. We reject the null hypothesis and find that SW1's TSSs and SW2's turbidity are negatively correlated. We reject the null hypothesis and find that SW2's TSS and SW2's turbidity are negatively correlated. The results of the Spearman's rank correlation can be seen in Table 1.

Figure 10

Turbidity



Note. Graph A shows Conductivity in the Hocking River sites; Graph B shows Conductivity in the Stormwater Wetland sites.

Table 1

TSS and Turbidity Correlation

	HR1 TSS	HR2 TSS	HR3 TSS	SW1 TSS	SW2 TSS
HR1 Turb	r = 0.923 p < 0.001	r = 0.985 p < 0.001	r = 0.984 p < 0.001	r = - 0.305 p = 0.362	r = - 0.396 p = 0.228
HR2 Turb		r = 0.889 p < 0.001	r = 0.854 p < 0.001	r = - 0.545 p = 0.299	r = - 0.549 p = 0.080
HR3 Turb			r = 3.0531 p = 0.014	r = - 1.309 p = 0.223	r = - 2.422 p = 0.039
SW1 Turb				r = 1.408 p = 0.193	r = - 0.467 p = 0.652
SW2 Turb					r = - 0.407 p = 0.694

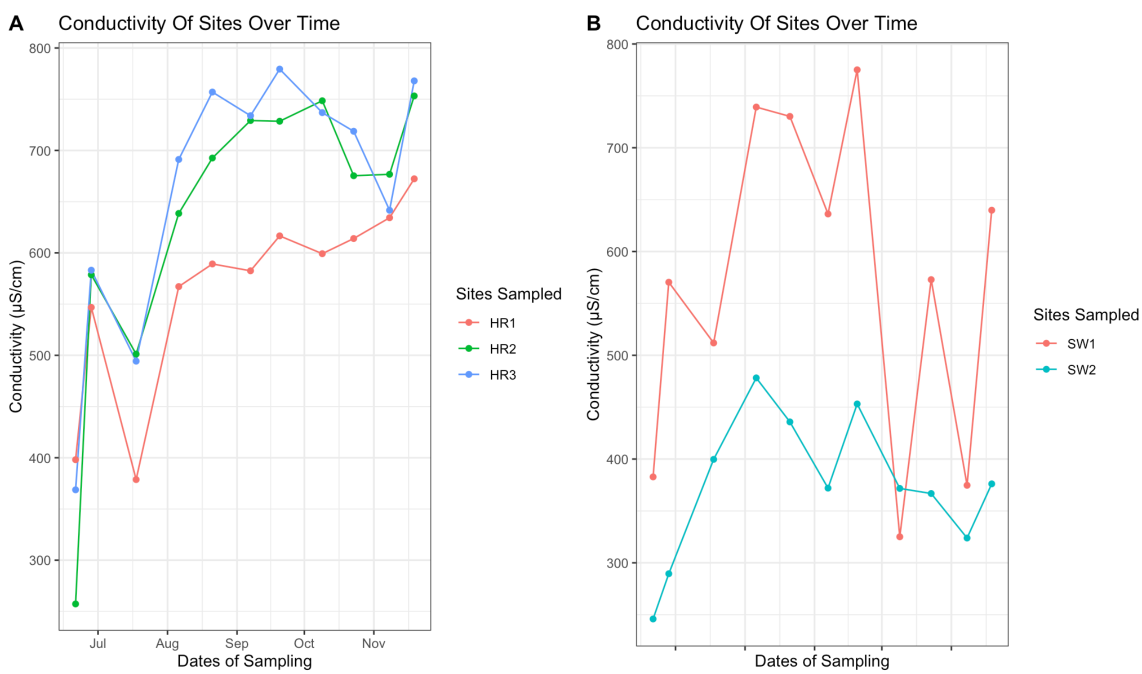
3.8 Conductivity

Conductivity in the HR sites followed a similar trend. In June and July, conductivity fluctuated between 257.3 µS/cm and 546.8 µS. From August to November, conductivity had less fluctuation. Between August and November, conductivity averaged at 609.4 µS/cm, 705.3 µS.cm, and 728.3 µS/cm at HR1, HR2, and HR3, respectively. In those months, HR1 averaged 107.4 µS/cm less than in HR2 and HR3. All the river sites averaged above the desired conductivity range in a stream, between 150 to 500 µS/cm (Behar, 1997).

Conductivity in the SW sites did not follow a similar trend but do align closely with TDS. Seen in figure 11, conductivity increases in June and August and in September and November it becomes inconsistent between each sampling event. Conductivity in SW1 averaged at 568.9 µS/cm while SW2 averaged at 373.9 µS/cm. SW1 was approximately 195.1 µS higher than SW2. SW2 was below 500 µS during the entire sampling period while SW1 was below this benchmark three times, once in summer and twice in fall.

Figure 11

Conductivity



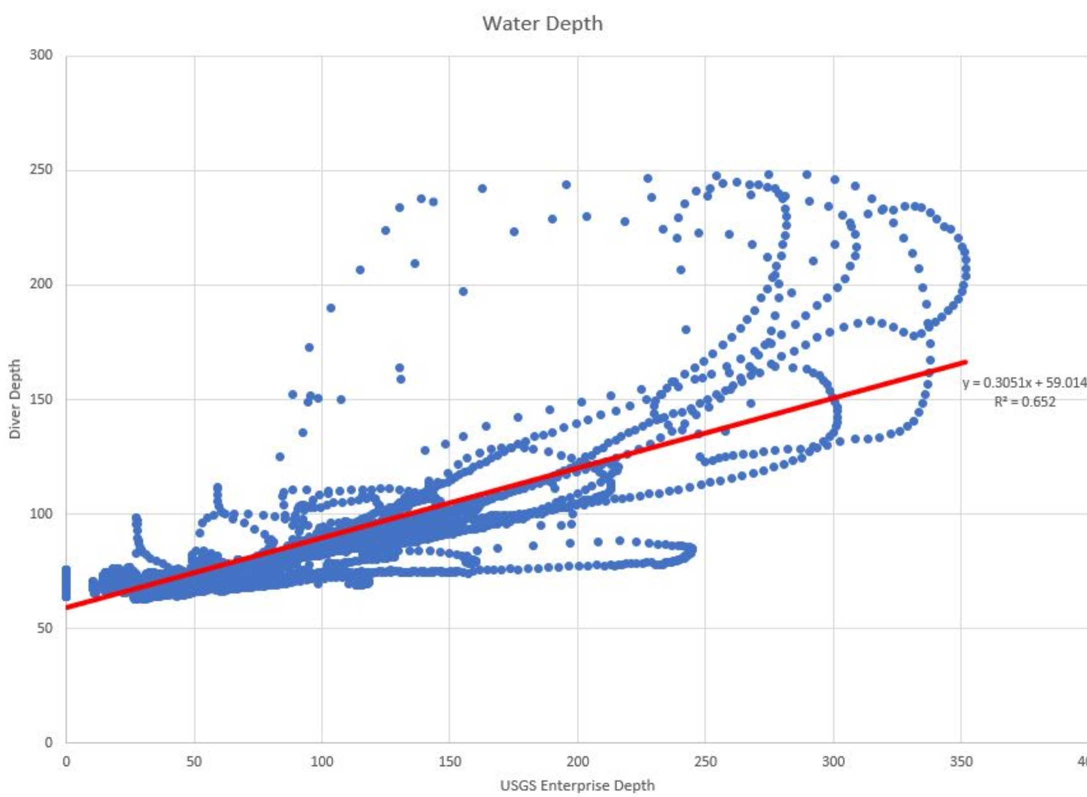
Note. Graph A shows Turbidity in the Hocking River sites; Graph B shows Turbidity in the Stormwater Wetland sites.

3.9 Water Depth

Data was collected from the Van Hessen diver and baro at site HR2 between April 26th, 2019 and September 27th, 2019. Sometime between the September 27th collection date and the November 19th end of sampling date, the Van Hessen diver had been washed away during a storm event. Due to this event, a linear regression was conducted modelling the relationship between the USGS stream gage at Enterprise and the collected Van Hessen diver data. The regression described the relationship between these two variables is shown in figure 12 giving an R^2 value of 0.652.

Figure 12

USGS Enterprise and Diver Linear Regression



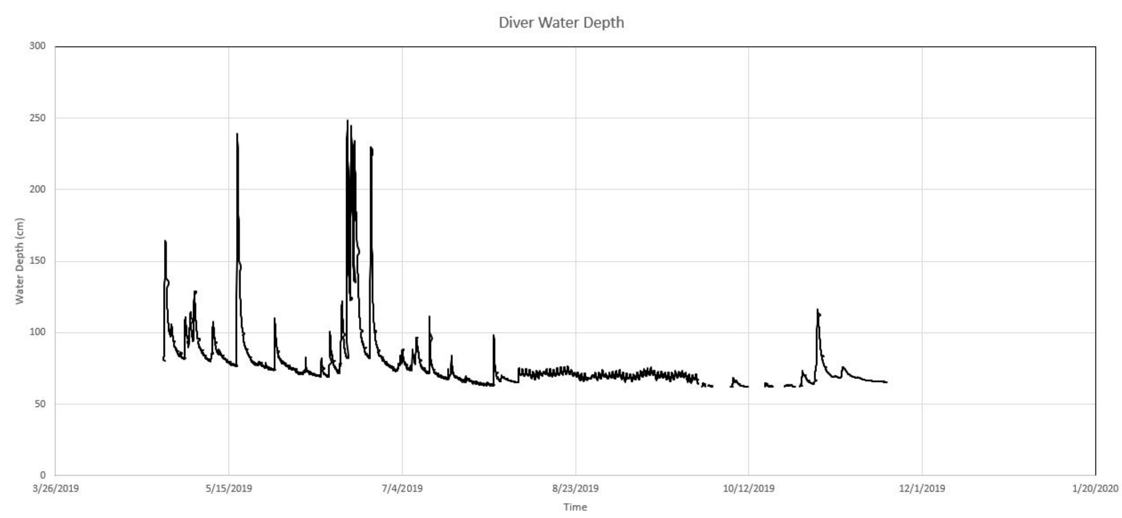
Note. The slope and R^2 value are to the right of the Linear Regression.

Equation 2 from this regression was then used to predict the water depth of the missing diver data as seen in Figure 13.

Equation 2 $y = 0.3051x + 59.014$

Figure 13

HR2 Water Depth



Note. Water depth of the Van Hessen water gage at site HR2.

The depth of water was highest between June 18th and June 24th, as well as on May 17th. The June13 rain events are significant as these events took place before the second field sampling date, June 28th. From July 14th until November 20th, the average water depth is 69.514 cm with one storm event in late October.

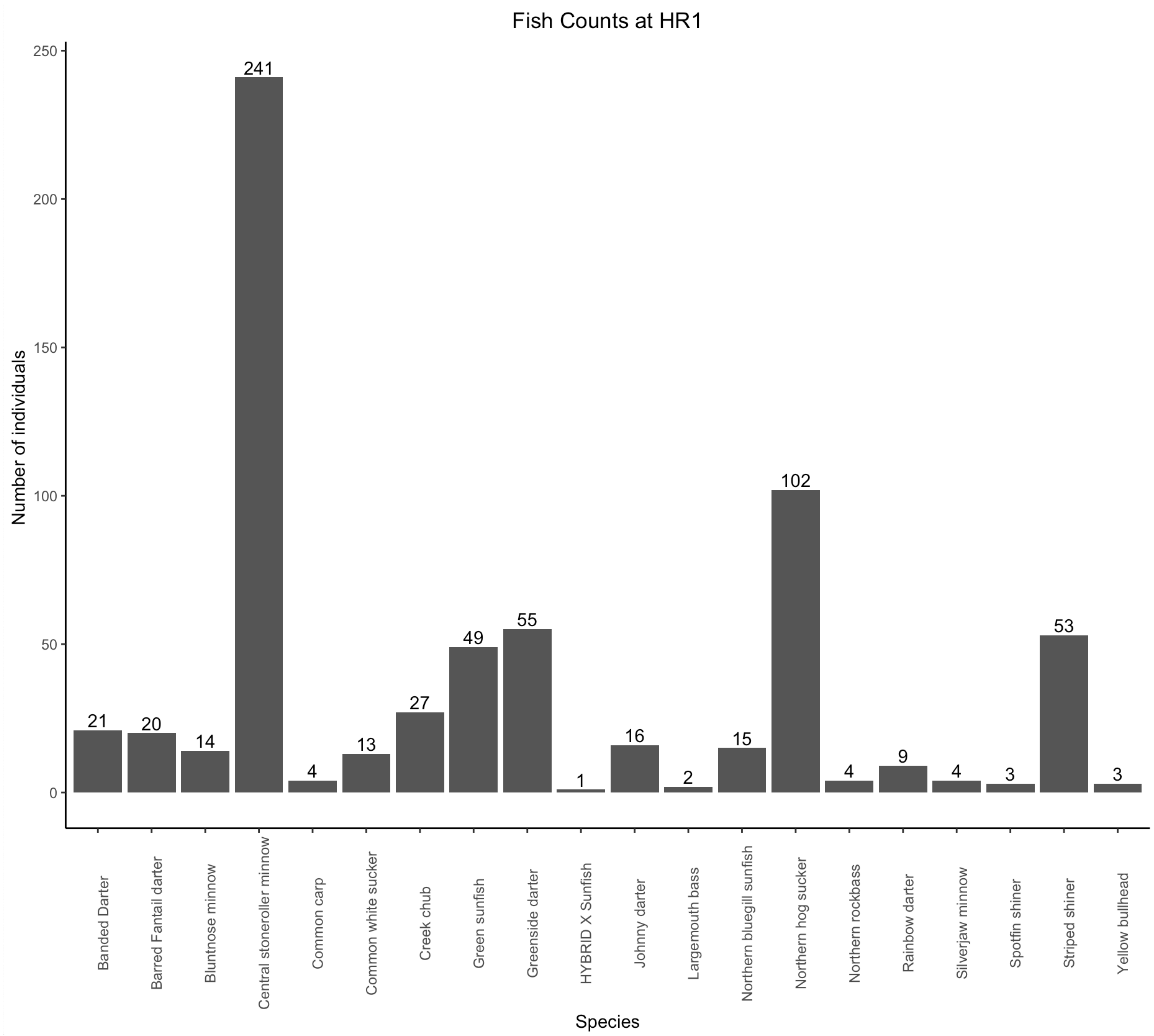
3.10 Fish

Overall, Hocking River fish scores decrease from upstream to downstream. HR1 has an IBI score of 54 which indicates exceptional water quality and a MIwb score of 8.9 that indicates very good water quality. HR2 has an IBI score of 48 which indicates very good water quality and a MIwb score of 8.2 that indicates good water quality. HR3 has an IBI score of 44 which indicates good water quality and a MIwb score of 9.6 indicating an exceptional water quality. HR3 shows the highest MIwb score which is likely due to the large size of two species of redhorse.

In HR1, there were 713 fish and 23 species caught. 20 species were native, there were 5 darter species, 3 sunfish species, 2 sucker species and 2 intolerant species. These species can be seen in Figure 14. 15.428% of the fish were tolerant species, 4.348% of fish were omnivores, 57.083% of fish were insectivores and 0.842% of species were top carnivores.

Figure 14

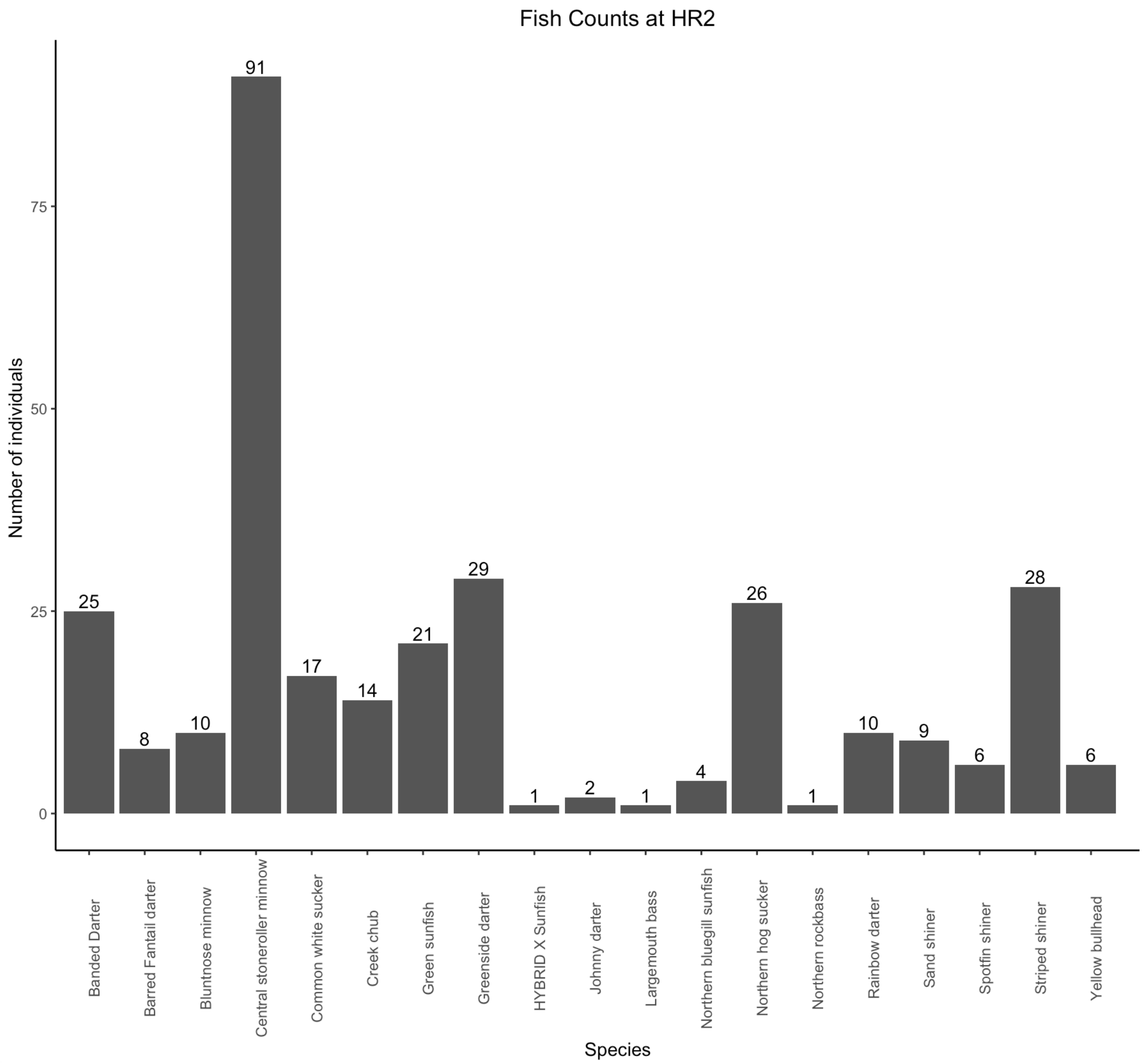
HR1 Fish



In HR-RM94, there were 310 fish and 20 species caught. 19 species were native, there were 5 darter species, 3 sunfish species, 2 sucker species and 2 intolerant species. These species can be seen in Figure 15. 21.935% of the fish were tolerant species, 8.710% of fish were omnivores, 56.452% of fish were insectivores and 0.645% of species.

Figure 15

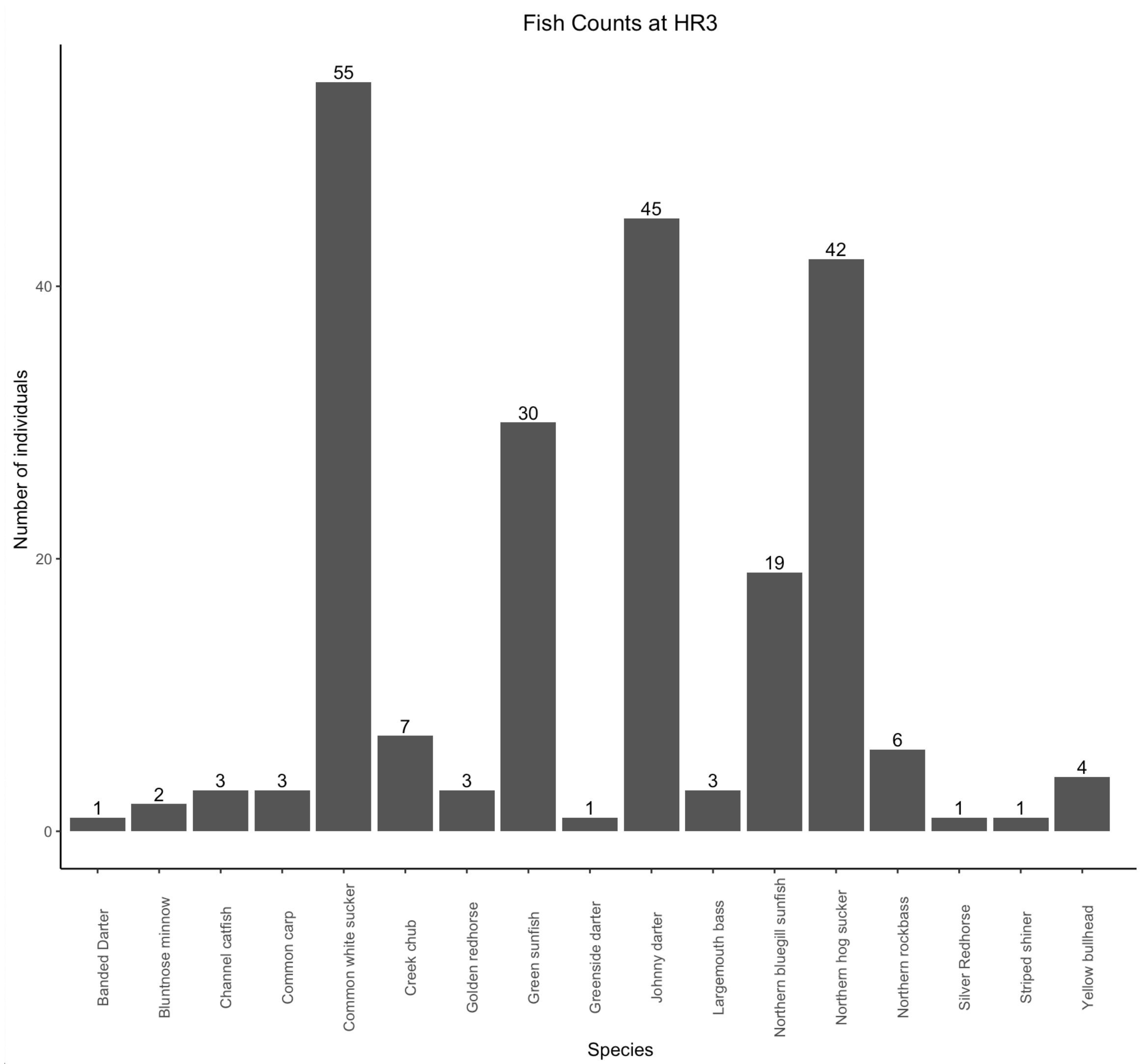
HR2 Fish



In HR3, there were 226 fish and 17 species caught. 16 species were native, there were 3 darter species, 3 sunfish species, 4 sucker species and 1 intolerant species. These species can be seen in Figure 16. 44.690% of the fish were tolerant species, 26.549% of fish were omnivores, 65.004% of fish were insectivores and 3.982% of species were top carnivores.

Figure 16

HR3 Fish

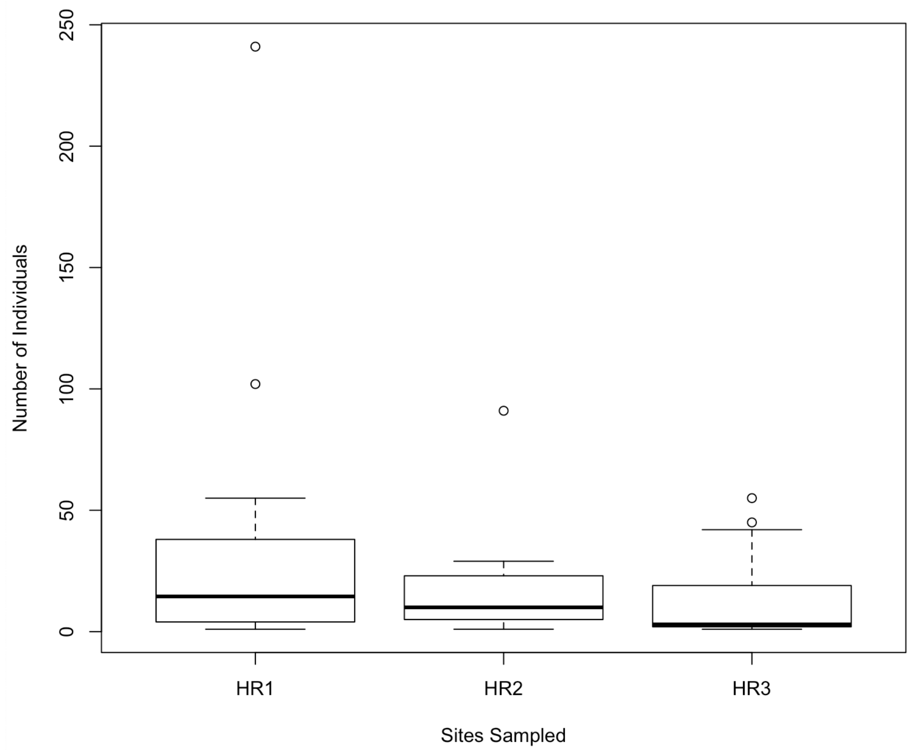


Hocking River fish species numbers and individual numbers decreased from upstream to downstream. HR3 is has the highest percentage of tolerant species, omnivores, insectivores and top carnivores but also has the fewest number of fish. HR2 has the lowest number of insectivores and top carnivores and HR1 has the lowest number of tolerant species and omnivores.

To see if there is a statistical difference between the three of these sites a Kruskal-Wallis ranked sum test was done. The null for this test is that the number of individuals have the same distribution in the HR sites. A box plot represents the distribution of individuals between sites in Figure 17. Using this test, we fail to reject the null, the number of individuals have the same distribution in the HR sites (Chi^2 =3.3892, df = 2, p-value = 0.18). A table of the Dunn post hoc test using the Bonferroni method for this test is found in Table 1.

Figure 17

Fish Boxplot



Note. Site go from upstream to downstream, left to right.

Table 2

Dunn post-hoc of Fish in HR Sites

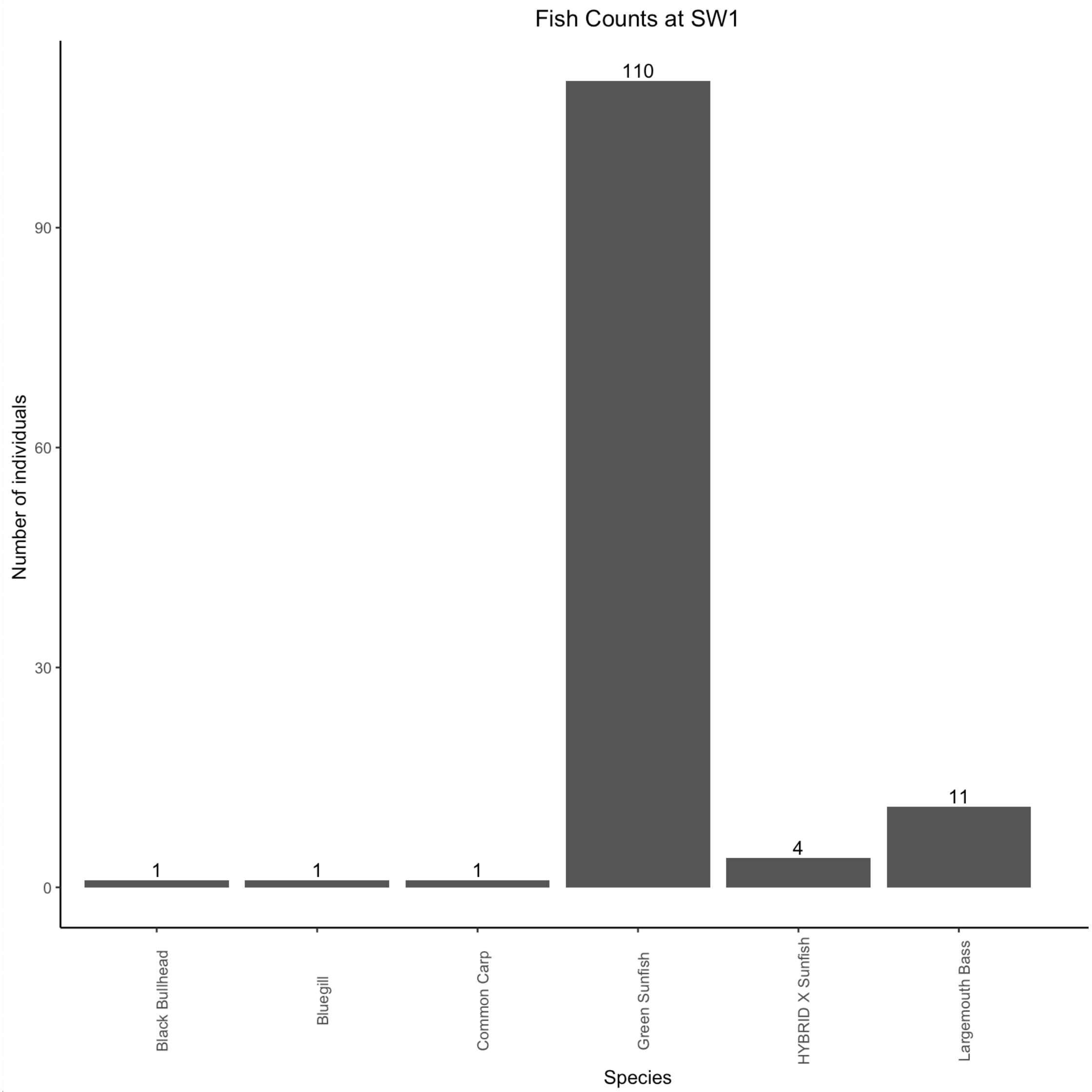
Comparison of Numbers by Sites		
	HR1	HR2
HR2	0.754173	
	0.6761	
HR3	1.836366	1.090852
	0.0995	0.413

Note. The top number is the z static and the bottom number is the p-value.

There is no index used for fish or invertebrates in a wetland habitat. However, using the same parameters we can compare fish species. SW1 was sampled but SW2 had too much silt making the site dangerous to sample fish in. As seen in figure 18, there were 128 fish and 6 species found in SW1. 110 of the total fish numbers were green sunfish, a highly tolerant fish. 5 species were native, there were 0 darter species, 2 sunfish species, 0 sucker species and 0 intolerant species. 90.625% of the fish were tolerant species, 0.008% of fish were omnivores, 86.719% of fish were insectivores and 8.59375% of species were top carnivores. SW1 has the least number of fish species and individuals. SW1 has the highest percentage of tolerant fish, insectivores and top carnivores compared to any other site. SW1 also has the lowest number of omnivores compared to all other sites.

Figure 18

SW1 Fish



Note. *Green Sunfish are the most abundant species and are highly tolerant.*

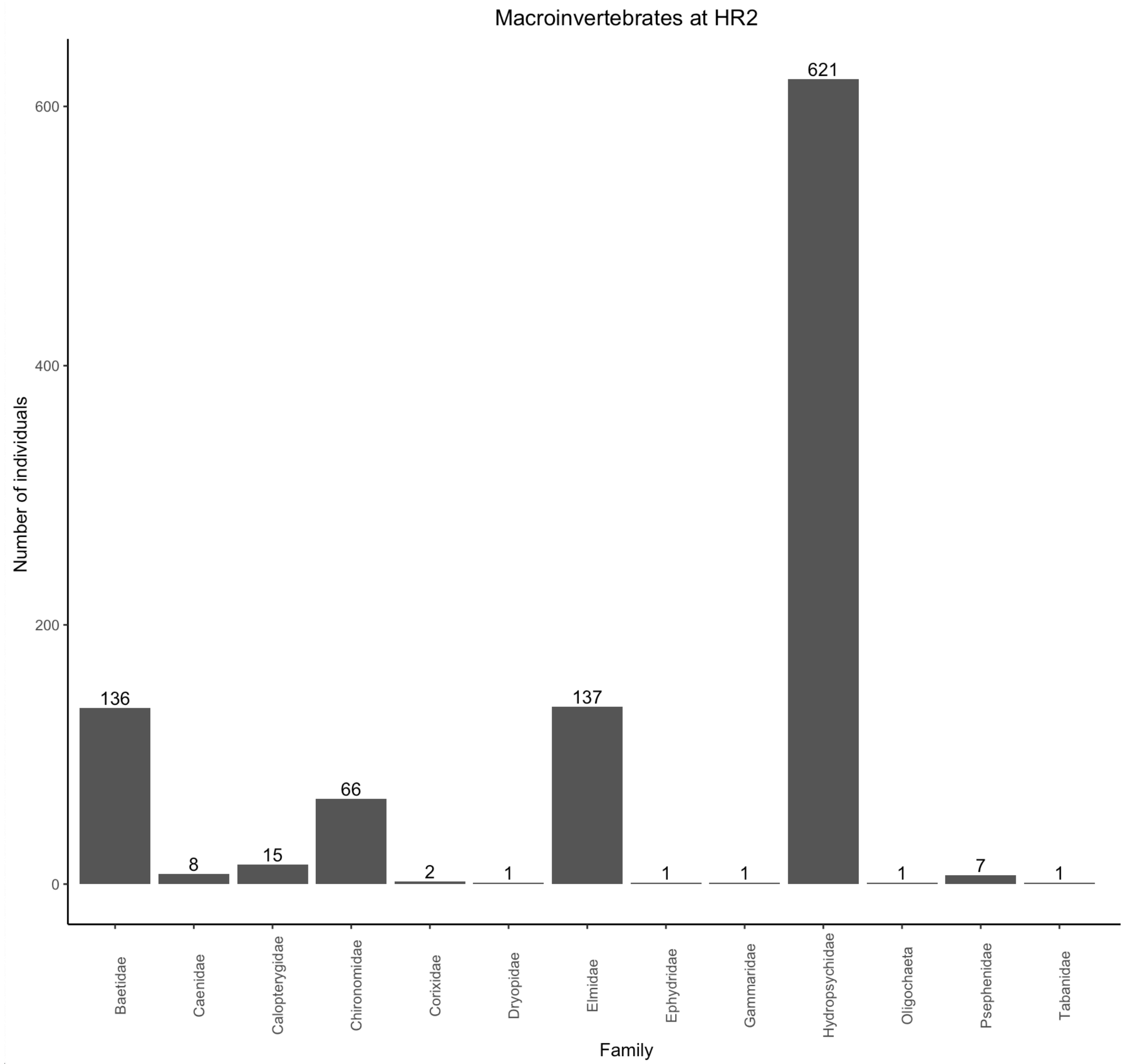
3.11 Invertebrate Species

Macroinvertebrate samples were taken at all sites in the month of August. The HR1 kick net sample jar was misplaced after being in the lab, so there will be a mention of species percent within that site, however a MAIS score will not be able to take place. HR2 was taken upstream to any output from the SW sites so this site will be used as the upstream reference site.

HR2 was sampled on August 3^{rd} and has a MAIS score of 11 giving the site a biological condition category of "Poor". 13 species were found at this site. 3 Families of scrapers, 5 families of Hapto, 2 families of Ephem, 2 Ephemeroptera, 0 Plecoptera, 1 Trichoptera and 4 intolerant families are what makes up this score. The three most common families found in HR3 were Hydropsychidae (621 individuals), Elmidae (137 individuals), and Baetidae (136 individuals). The total number of individuals found at this site was 997 and can be seen in Figure 19.

Figure 19

HR2 Macroinvertebrates

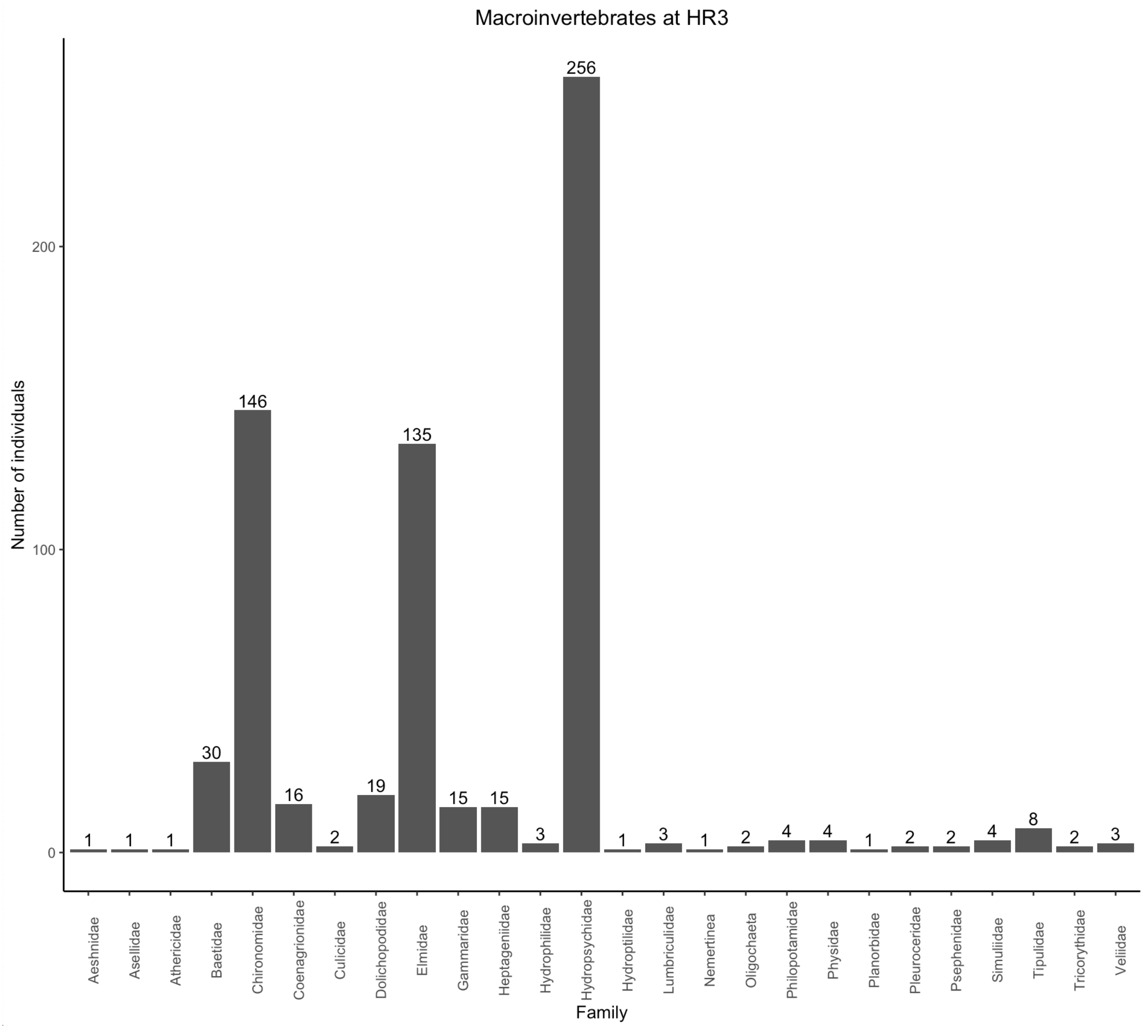


HR3 was sampled on August 8th and has a MAIS score of 13 giving the site a biological condition category of "Good". 26 species were found at this site. 4 Families of scrapers, 13 Families of Hapto, 3 families of Ephem, 3 Ephemeroptera, 0 Plecoptera, 3 Trichoptera and 11 intolerant families are what makes up this score. The three most common families found in HR3 were Hydropsychidae (256 individuals), Chironomidae

(146 individuals), and Elmidae (135 individuals). The total number of individuals found at this site was 677 and can be seen in Figure 20.

Figure 20

HR3 Macroinvertebrates

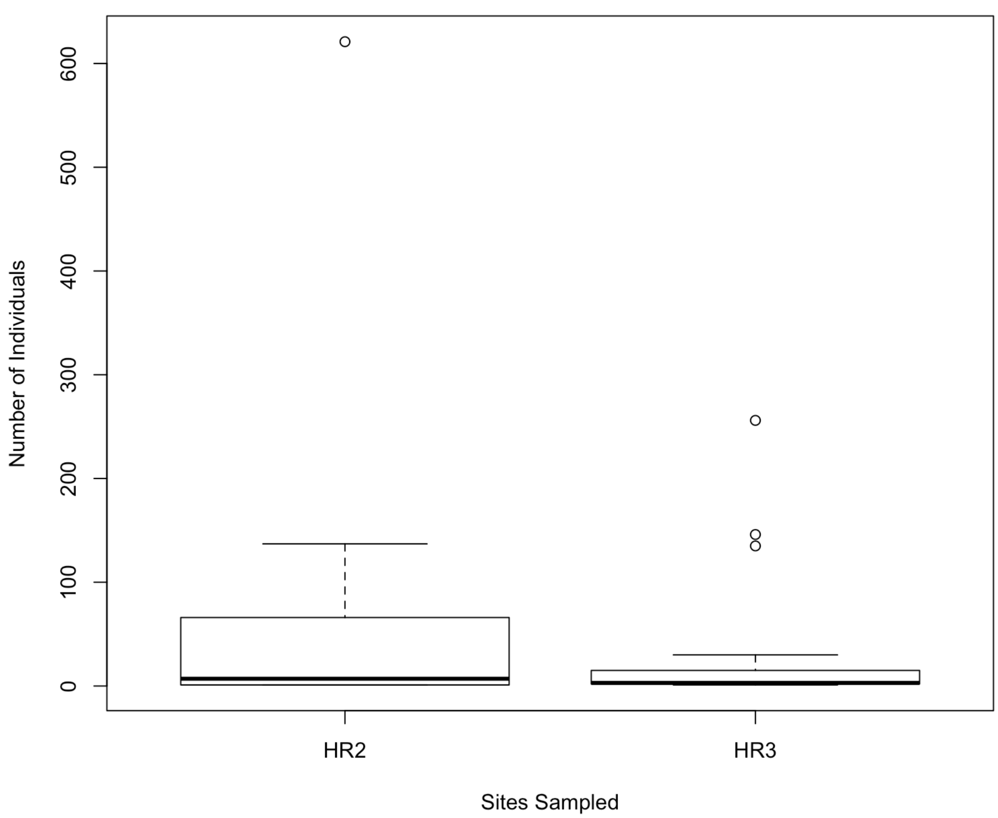


Note. Hydropsychidae, Chironomidae, and Elmidae are the most the most abundant species.

To see if there is a statistical difference between the three of these sites a Kruskal-Wallis ranked sum test was done. The null for this test is that the number of individuals have the same distribution in the HR sites. A box plot represents the distribution of individuals between sites in Figure 21. Using this test, we fail to reject the null, the number of individuals have the same distribution in the HR sites ($Chi^2 = 0.022808$, df = 1, p-value = 0.88).

Figure 21

HR Site Macroinvertebrate Boxplot

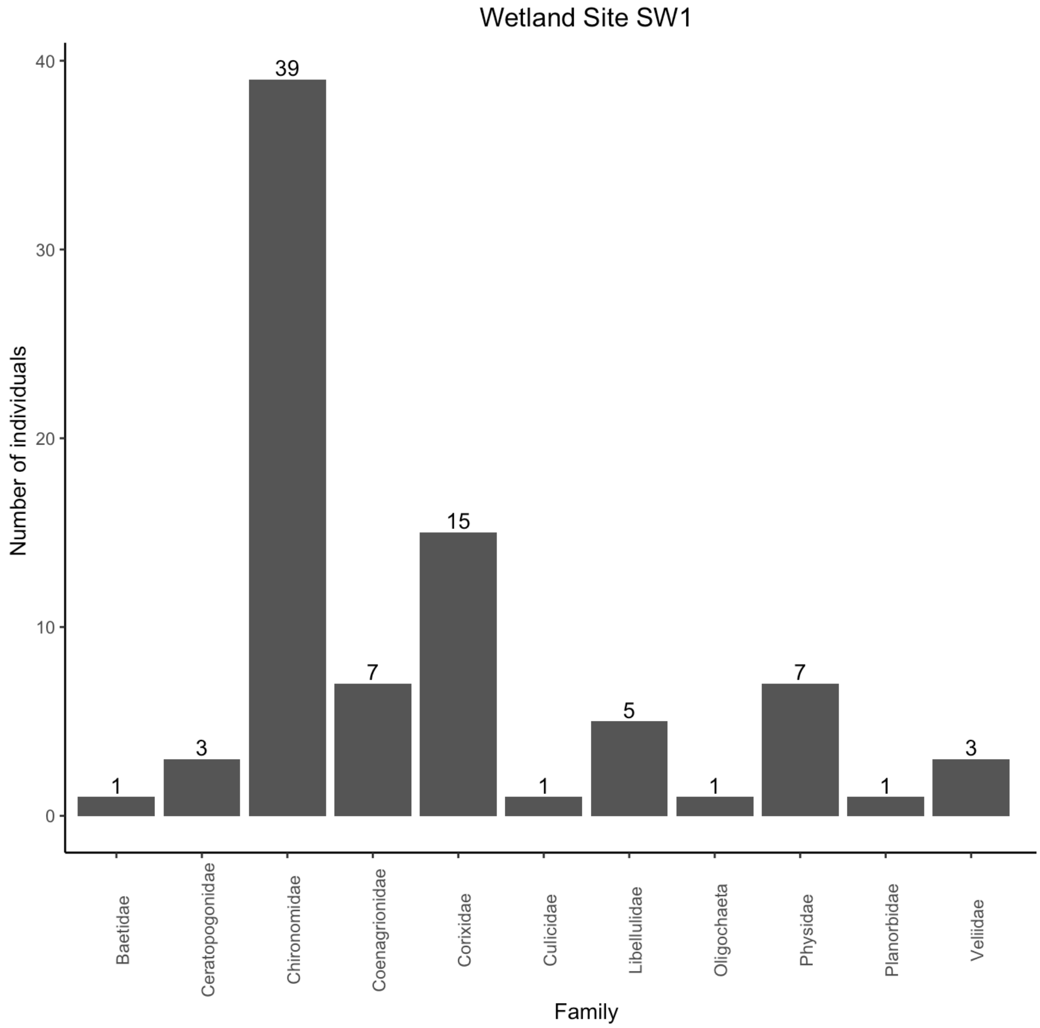


Note. Sites are shown upstream to downstream, left to right.

SW1 was sampled on September 16th, there is no MAIS scores for wetland macroinvertebrates. 10 species were found at this site. 0 Families of scrapers, 2 Families of Hapto, 1 family of Ephem, 1 Ephemeroptera, 0 Plecoptera, 0 Trichoptera and 0 intolerant families are what makes up this score. Shown in figure 22, the two most common families found in HR3 were Chironomidae (39 individuals) and Corixidae (15 individuals). The total number of individuals found at this site was 83.

Figure 22

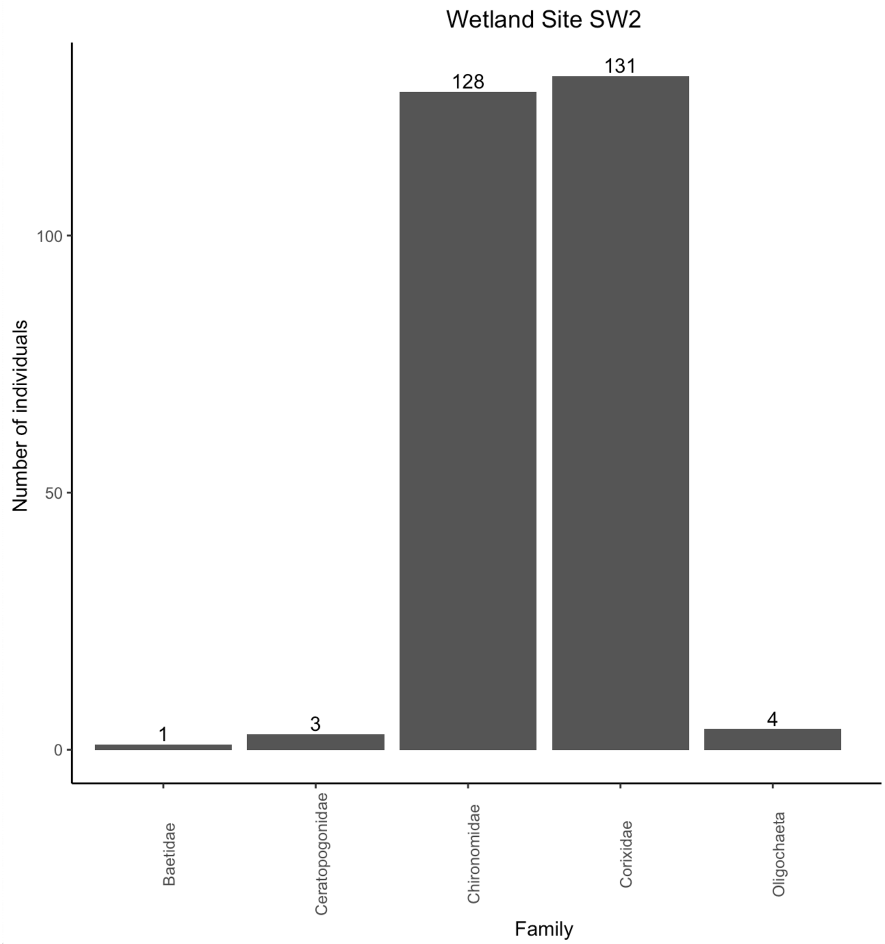
SW1 Macroinvertebrates



SW2 was sampled on September 20th, there is no MAIS scores for wetland macroinvertebrates. 5 species were found at this site. 0 Families of scrapers, 1 Family of Hapto, 1 family of Ephem, 1 Ephemeroptera, 0 Plecoptera, 0 Trichoptera and 0 intolerant families are what makes up this score. Shown in figure 23, the two most common families found in HR3 were Corixidae (131 individuals) and Chironomidae (128 individuals). The total number of individuals found at this site was 267.

Figure 23

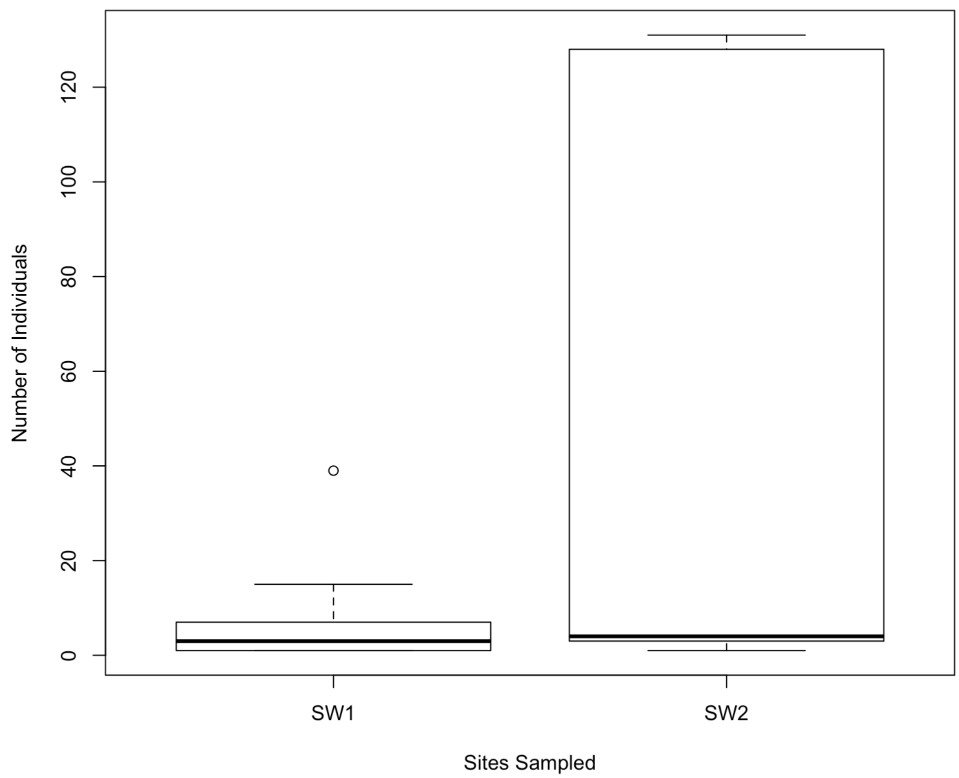
SW2 Macroinvertebrates



To see if there is a statistical difference between the three of these sites a Kruskal-Wallis ranked sum test was done. The null for this test is that the number of individuals have the same distribution in the SW sites. A box plot represents the distribution of individuals between sites in figure 24. Using this test, we fail to reject the null, the number of individuals have the same distribution in the SW sites ($Chi^2 = 0.74948$, df = 1, p-value = 0.3866).

Figure 24

SW Site Macroinvertebrate Boxplot



10 crayfish traps were deployed at SW sites 1 and 2 on September 28th at 9pm and collected at 10am the following day. There were no crayfish found within any of the traps. This is suspected to be caused by raccoon activity due to footprints, scat and movement of traps.

Chapter 4: Discussion

Habitat

The habitats in the Hocking River and wetland vary within and between water bodies. The QHEI score of HR1, found at RM 93.6, was 66 and HR2, found at RM 92.6, was 66.5. These sites fall in between the Ohio EPA 2004 sites, RM 96.8 and RM 91.9, that received a QHEI score of 72 and 52, respectively. HR3, found at RM 91, scored a 36.5 which is scored 15.5 lower than RM 91.9 in 2004 and is scored 32.5 lower than what the EPA found at RM 89.4 in 2004 (Ohio EPA, 2009a). The QHEI scores found in this study indicate that habitat quality has declined in the last 10 years. Some of the reasons this could have declined is because this study shows that the channelization along the Hocking River has been “Recent or No Recovery” while the Ohio EPA says it is “Recovering Channelization” and “Recent or No Recovery” making the score 2 points lower (Ohio EPA, 2009c). The EPA also had added points in their survey for pool/glide and riffle run quality (Ohio EPA, 2009c) which was very underdeveloped in the HR3 survey conducted for this study. Since the QHEI could vary from construction during the last 15 years there could be some differences. HR3 was sampled 1 mile from previous EPA sampling locations so there is no background knowledge on the sampling location. Overall, the two upstream sites scored a higher QHEI at 66.5 and 66 showing that they are high quality waters unlike the downstream site scoring a 36.5 indicating it is a “poor” quality habitat.

SW1 was observed to be a Modified Category 2 wetland. This category indicates that the wetland is degraded but restorable (John J. Mack, 2001). Restorable wetlands can support a moderate amount of habitat, hydrological or recreational activities and can be expected to have "fair" or "good" quality (John J. Mack, 2001). SW2 was observed to be a Category 1 wetland. This means the wetland supports little amount of life or habitat (John J. Mack, 2001). Category 1 wetlands usually have limited riparian buffers and are heavily disturbed by stormwater inputs, animal grazing, and other factors. This makes these waterbodies "limited quality waters" that have limited potential to be restored (John J. Mack, 2001).

SW1 scored an ORAM score of 35.5 indicating that is it a modified category 2 wetland and SW2 scored an ORAM score of 20 indicating it is a category 1 wetland. Both of the SW site's ORAM v. 5.0 scores were in the range expected when compared to a study conducted by Mack and Micacchion in 2007. About 60% of urban wetlands within Franklin County, Ohio, were either poor (26%) or fair (33%) (J. J. Mack & Micacchion, 2007). Both SW1 and SW2 can be considered either a riverine or depressional wetland. This is because they are within the Hocking River floodplain but are mostly disconnected in a constructed basin. Depressional wetlands tend to be in poorer condition than riverine wetlands in an urban environment (J. J. Mack & Micacchion, 2007). Since these wetlands can be observed as either a Riverine or Depressional wetland, this study will use the Hydrogeomorphic (HGM) Wetland Classification System (USDA, 2008) is used to better describe the results from the ORAM scores. Using the HGM classification, SW1 and SW2 would be a RIVERINE: Depression, High Lime Till Plain, *loamy*. With less plant life and a high number of disturbances found in SW2, it aligns more closely to Mack and Micacchion's observations of depressional wetlands. SW1 has fewer disturbances and a larger variety of vegetation present.

With SW1 being a Modified Category 2 wetland and being next to the AHA! Children's museum, it has the highest potential to be used as a good restoration and education site. SW1 is adjacent to the river so there are opportunities to explain how the two water bodies are connected. It is also a good example of nature in the city and how city and community management can help introduce healthier habitats. SW1 can still be improved, but that allows for better community education of wetlands and earth sciences.

Water Quality

ORP in all of the sites are in a normal range, all within 30 – 170 mV. As seen in Figure 6, HR1 has the highest ORP in the river sites within the first half of the sampling period when the average water temperature in all sites was 22.3 ^{o}C, later following the same pattern as the other river sites. As temperature decreases in the Fall, ORP becomes more sporadic and no longer follows a linear path. As seen in Figure 6, the lowest ORP sampling date for HR1 was on September 7th when the water temperature was 20.3 ^{o}C while the lowest ORP sampling date for HR2 and HR3 was on October 9th when the water temperature was 18.1 in HR2 and 16.9 in HR3.

According to Kjelland et al., 2015, TSS and turbidity are strongly correlated and are likely to give the same results. When referring to Table 1, all of the HR sites are positively correlated while the SW sites are not all positively correlated. So, while they are correlated, we cannot conclude that they are giving the same results. This could be because this study collected data using a turbidity tube rather than a turbidity reader that directly reads in the NTU values. Readings with the turbidity tube are measurements that can be subjective to each person. The same person sampled all of the same sites on days sampled and the TSS reading gives a less subjective reading.

Turbidity and TSS fluctuate more in the months of July and August, leveling out throughout the rest of the Sampling period. Turbidity and TSS are higher in SW2 than in SW1. Turbidity can reduce the amount of light that passes through water decreasing the photosynthesis rate of plants (Kjelland et al., 2015) resulting in lower DO (Kjelland et al., 2015; Sorensen et al., 1977). We see a lower number of plants in SW2 compared to SW1; but there are higher concentrations of DO in SW2 than there are in SW1. The higher concentrations of DO in SW2 could also be impacted due to decomposition of algae or plant matter. Low DO can be a result of seasonality change like temperature or stratifications in a lentic water body but have also be a result of input from anthropogenic nutrients and organic matter (Pollock et al., 2007).

The levels of TSS and turbidity found in SW1 and SW2 indicate that there is less suitable habitat for photosynthetic organisms due to sedimentation. Increased levels of sediment also affect life cycles of fish, usually reducing their growth rate (Sorensen et al., 1977). Sedimentation in these wetlands creates less ideal habitat for macroinvertebrate populations (Sorensen et al., 1977). Sedimented in the SW sites could also have pollutants because received from the River Valley Mall. Ephemeroptera, Plecoptera and Trichoptera (EPT) species have been found to be sensitive to these urban runoff (Chang et al., 2013) and there was only one species of Ephemeroptera found in SW2. With lower food availability and lower quality habitat, it will be harder for fish species to thrive.

With lower food availability and lower quality habitat, this could be a factor in less diversity in the fish population in SW1.

Conductivity in SW1 and HR sites are regularly above 500 µS/cm. This indicates that there are high levels of salt or other substances in the water. According to the Ohio EPA "A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams" the aquatic life benchmark for the ecoregion of Appalachia is approximately 300 µS/cm (U.S. EPA (Environmental Protection Agency), 2011). It is possible that conductivity levels in SW1 and HR sites are above the desired 500µS/cm due to the fact that conductivity has been found higher in SE Ohio compared to levels in Kentucky and WV (U.S. EPA (Environmental Protection Agency), 2011).

Conductivity and TDS were strongly related. Many studies have found that there is not a linear relationship between conductivity and TDS (McNeil & Cox, 2000; Walton, 1989); however, this study suggests otherwise. Conductivity in the river sites was highest between September and November, which was the same time TDS was high. Seen in Figure 9 and 11, conductivity and TDS are lowest in SW2. All HR and SW sites follow a similar relationship throughout the sampling period. The only event that conductivity and TDS are different is on September 20th where HR1 has a low TDS and conductivity remains high.

Temperature both high and low can also cause a reduction of the number of macroinvertebrates and fish in ecosystems (Beitinger et al., 2000; Burgmer et al., 2007; Collas et al., 2019; Hogg et al., 1995; van Vliet et al., 2012; Yoder & Emery, 2003). The temperature in SW1 reached 44.5^{o}C during one sampling event, high enough to cause fish kills of some of the most tolerant freshwater fish (Beitinger et al., 2000; Sorensen et al., 1977). Other than that sampling event, temperatures in SW1 remained at 30^{o}C or lower. SW2 was measured at 34.7^{o}C twice and was regularly above 30^{o}C from July to September. Likely, due to the lack of shade present in SW2, data showed that temperature is higher in SW2 than in SW1. For many sensitive species, studies have shown that above 30^{o}C becomes an Upper Incipient Lethal Temperature (UILT) (Yoder & Emery, 2003). The green sunfish were likely one of the most common fish found in SW1 because their UILT is 40^{o}C and their optimum preferendum is 30.6^{o}C making it one of the most heat tolerant fish species (Beitinger et al., 2000; Yoder & Emery, 2003).

pH was found within the desired range within all site except for SW2 on October 9th when pH was 9.39 which was slightly alkaline.

Fish

The Hocking River, in 1991 at RM 95.2 had an IBI score of 35 and an MIwb of 8.2, at RM 92.2 had an IBI score of 27 and an MIwb score of 6.5 (Ohio EPA, 1991). The Hocking River in 2004 at RM 96.8 had an IBI of 42, at RM 91.9 an IBI score of 32 (Ohio EPA, 2009a). IBI and MIwb scores in all three HR sites were higher than their closest EPA sampling locations from 1991 and 2004. HR1 scored an IBI score of 54 indicating exceptional water quality and MIwb score of 8.9 indicating very good water quality. HR2 scored an IBI score of 48 indicating very good water quality and MIwb score of 8.2 indicating good water quality, and HR3 scored an IBI score of 44 and MIwb score of 9.6. During the 2004 EPA sampling events, RM 96.8 scored an IBI score of 42 and did not have an MIwb score, RM 91.9 had an IBI score of 32 and MIwb score of 6.8, and RM

89.4 scored an IBI score of 34 and an MIwb score of 6.6 (Ohio EPA, 2009a). All of the IBI and MIwb scores indicate that HR1, HR2, and HR3 meet Warm Water Habitat (WWH) standards (Yoder & Rankin, 1998).

The reason scores may decline the further downstream sites are sampled is likely due to the habitat quality. The water chemistry in the HR sites are very similar with only pH and TDS being slightly lower in HR1 than the other HR sites. Since these sites are all chemically similar, it can be inferred that as habitat quality declines, the fish quality also declines.

The species diversity is higher in the HR sites than in the SW sites. Central stoneroller is the most commonly found species in both HR1 (241) and HR2 (91) while the Common white sucker (55) is the most common species found in HR3. According to the Grabarkiewics and Davis' "An introduction to freshwater fishes as biological indicators", Stonerollers and White suckers range from "tolerant" (Halliwell et al., 1999) to " moderately intolerant" (Jester et al., 1992; Pirhalla, 2004). The number of common white suckers in HR3 (55) is just 10 more individuals than johnny darters (45), which is "intolerant" (Jester et al., 1992) to "intermediate" (Halliwell et al., 1999) and 13 more individuals of northern hogsucker (42) which is an "intermediate" (Halliwell et al., 1999) to "intolerant" (Jester et al., 1992; Pirhalla, 2004) species. While some of the more dominant species in HR1, HR2, and HR3 are tolerant species, as see in Figures 13 - Figure 15 there is a high abundance of intolerant fish species which makes these sites meet WWH.

It was found that 85% of the total fish population in SW1 were green sunfish. These species have been found to range between "moderately intolerant" (Pirhalla, 2004) to "tolerant" (Halliwell et al., 1999; Jester et al., 1992; Karr et al., 1986). The dominance of the green sunfish in this wetland indicates poor water quality. Unlike the HR sites that had a dominant species, seen in Figure 17, there was less fish diversity in SW1, and the fish species found were also highly tolerant.

SW1 is likely to have low species richness due to the low DO levels and high temperatures it has in summer months. High levels of conductivity and TDS could also have impacted the fish species in this water body. With species richness in SW1 being low, we can hypothesize that there are fewer organisms found in SW2. SW2 had higher levels of turbidity and temperature which are both qualities that could diminish the number of fish that would be found.

Macroinvertebrates

Macroinvertebrates in the Hocking River sites obtained good MAIS scores while wetland sites had less intolerant species and dominant tolerant species. HR2 has a MAIS score of 11 while HR3 has a MAIS score of 13. This gives the opposite response that the fish IBI scores by indicating that biological community improves from upstream to downstream. This could be a result of a dominance of one species over the others. As seen in Figure 18 HR2 is dominated by Hydropsychidae (621) with no other families over 140 individuals. Seen in Figure 19 HR3 is dominated by Hydropsychidae (256) with Chironomidae (146) and Elmidae (135) being the next most common families. Hydropsychidae are the most commonly found caddisfly within this region (Harris &

Lawrence, 1978). The species within this filter feeding family vary in their tolerances (Harris & Lawrence, 1978).

There is no statistic difference between the number of individuals HR Sites and in SW sites. Family richness is higher in SW1 with 11 families than in SW2 that has 5 Families. The most common family in SW1 is Chironomidae with 39 individuals. While in SW2 the two most common families are Corixidae with 131 individuals and Chironomidae with 128 individuals. Chironomidae ranges from “moderately intolerant” to “tolerant” while Corixidae is “Facultative” (Ohio EPA, 2019). SW2 has two highly dominant species this helps indicate that it is poor water quality while SW1 does not have one family that is dominant. Comparing between the HR sites and SW sites, family richness is higher within the HR sites.

The low family richness in SW1 is likely a result of high sedimentation in the wetland. There is less light availability for food and there are likely pollutants that have entered the wetland from the River Valley Mall. Many species are sensitive to pollutants and high levels of sedimentation indicating that the pollutants in the wetland would need to be studied in the future.

Museum Application

The AHA! A Hands-On Adventure, A Children’s Museum has shown interest in including more outdoor education. In late 2018, the museum opened a nature playscape that their website says is intended for self-engaged family exploration (*ABOUT*, 2015). The museum and city have shown efforts to move forward with an outdoor trail system.

Introducing a trail off this space and involving more community-based science education would be a good next step.

Traditionally outdoor education focuses on adventure, but in recent years, a focus on community and individual wellbeing and environmental stewardship has become popular (Sabet, 2018). Outdoor education can benefit a person emotional and physical body as well as a person's ability to problem solve (Sabet, 2018). Trail signs are one way to expand outdoor education.

It is ideal for a trail sign to be between 30-100 words (Serrell, 1996; Wandersee & Clary, 2007). Serrell has written two books, *Exhibit Labels: An Interpretive Approach*, Edition 1 and 2 on the ideal way to create a sign for viewers. These books, cover that a sign should begin with information related to the reader, have sentences that vary in lengths, have short blocks of paragraphs, include heading and subheadings, disperse opportunities, have a snappy ending, etc (Serrell, 1996). If signs are developed in a way that is inclusive, they can promote science discussion and questioning (Wandersee & Clary, 2007).

Information from this study can be used and is offered to the museum to inform the community. As a modified category 2 wetland, SW2 is an ideal candidate for placed based education. Developing a trail in the neighboring field, it could connect to the wetland where SW2 was sampled. Signs on the plant species found from a previous inventory, fish and insects found as well as a history of the community efforts in including bird boxes could act as a place-based learning opportunity.

Place-based education is when education can take place in a local region to reconnect people with nature and their environment (Endreny, 2010; Zhang & Lai Lei, 2012). This kind of education can encompass many complex topics. These topics in a wetland/river setting can include: physical and biological components, water cycle/watershed concepts, human and natural influences on a watershed, and mathematics through a hands on observational approach (Endreny, 2010). This can then develop an emotional attachment to a place (Endreny, 2010) and increase locals interest to participate in local tourism (Zhang & Lai Lei, 2012).

Chapter 5: Conclusions and Deliverables

This study explores and expands on the present knowledge of the stormwater wetland behind the AHA! Museum and Hocking River headwaters. It is the first study in a 15-year time period that quantifies the biotic variables and field parameters in the headwaters of Hocking River. Water chemistry in this study area has only been studied four times in the past; biological species in these sites have only been studied twice. This study is also the first in the stormwater wetland quantifying biotic variables and water chemistry. Studying this in Lancaster, Ohio, an urban and agricultural area with high pollutant runoff potential provides information that gives a better understanding of the efficiency of stormwater wetland management and informs future management and outreach.

Implementing this study with a partnership with the AHA! A-Hands On Adventure Children's Museum has created opportunities for increased community education of wetland and river ecosystems. This research has gathered data resulting in educational material for the museum to engage the local community. Information gathered has also been presented to the city of Lancaster, encouraging efforts to increase riparian corridors.

Currently Lancaster, Ohio, has shown an effort to increase riparian corridors, but community leaders have shown struggles in implementing this (Fairfield 2018). This study has presented information that shows the benefits of a riparian corridor. Having this project connected with the AHA! Children's Museum will allow for more hands-on education that will continue to engage the community in outdoor recreation and the benefits of maintaining wetland and stream systems.

The City of Lancaster and other stakeholders received an Executive Summary of the data collected which can be seen in Appendix A. This summary concludes that having more fauna around the wetland would create more shading and habitat areas that would create a healthier wildlife habitat. Adding more inlet structures creating more flow between the river and wetland complex would also help cool down temperatures in the wetlands.

The headwaters of the Hocking River improved in quality since the Ohio EPA sampled in 2004. Fish IBI scores are 40 in HR2 and 44 in HR3, the qualifying score for a warm water habitat is 40. In 2004, fish IBI scores were 32 at HR2 / RM 92.2 and 42 at HR3 / RM 90.8. Fish scores lower going downstream but have improved significantly in the last 10 years. MAIS scores in the Hocking River indicated good water quality for a headwater ecosystem. QHEI scores have declined since they were sampled last sampled in 2004. Total dissolved solids go up going downstream but turbidity remains the same in all river sites. pH in HR1 is low during summer months compared to HR2 and HR3, but from September to November all pH findings are similar. Dissolved Oxygen in HR2 is higher than HR1 and HR3 throughout the entire sampling period. Conductivity is lowest in HR1 throughout the entire sampling period. Temperature, pH, Conductivity, Turbidity and TDS go up further downstream.

Both SW1 and SW2 have large amounts of sediment. SW1 is a modified category 2 wetland showing it is a higher quality habitat than SW2, a category 1 wetland. There is little plant life within and around SW2, which causes high temperatures and total suspended solids in the waterbody. Temperature, total suspended solids, pH, dissolved oxygen, and turbidity are regularly higher in SW2 than in SW1. It is likely that dissolved oxygen is lower in SW1 because of decomposition of algae and plant matter. Conductivity and total dissolved solids are higher in SW1 than in SW2. Hess bucket samples for macroinvertebrates found multiple high tolerant individuals and low family richness within both sites. These scores suggest poor water quality in both wetlands.

Overall, data suggests that both SW1 and SW2 act as catchment basins, reducing the amount of sediment and runoff that flows into the Hocking River. The study results and the ORAM habitat analysis have shown a few ways that the habitat quality in the stormwater wetland could be improved. If one side of the wetland is to become a site for education opportunities, SW1 is the ideal location to create more habitat. It is close to the AHA! Children's museum and it is also next to where the bike path runs against the Hocking River. SW1 is a Modified Category 2 wetland which according to the Administrative Code Rule 3745-1-54 (C) is a mid-grade wetland that is degraded but restorable (J. J. Mack & Micacchion, 2007). With a little bit of habitat restoration, it could easily be classified as a Category 2 wetland which is equivalent to a Warm Water Habitat (WWH) river ecosystem (J. J. Mack & Micacchion, 2007).

In the stormwater wetland, there are high levels of sedimentation, areas around the wetland have been mowed or are being farmed and also have been clear cut for industry and residential areas. To reduce the amount of sediment discharging to the river, increasing the size of the riparian zone or having more dense vegetative cover would slow the inflow of sediments (Skagen et al., 2008). Buffers that already are established also need to be maintained as some plant species can accumulate high amounts of nutrients and may need to be reseeded (Skagen et al., 2008). Sediment removal could also be a benefit to the wetland. Removal of sediment could help lower nutrient availability when at least 20 cm is removed (Klimkowska et al., 2007), it can also assist removal of invasive species, and increase seed germination (Hausman et al., 2007) to benefit ecosystem function. Both increased vegetative cover and sediment removal in SW1 and SW2 would be beneficial since they are connected to each other. These efforts in SW1 could allow more native species to grow; while in SW2, these efforts could introduce plants within the wetland creating cooler waters and fish habitat.

All sites in the Hocking River meet WWH based on their Fish IBI and MAIS scores. SW1 and SW2 could see a variety of benefits if they were connected with the Hocking River. Temperatures in the wetlands would cool down and the water would be less stagnant (Collas et al., 2019; Kurylyk et al., 2015). These cooler temperatures would create better habitat to increase species diversity and allow the wetlands to become a refuge for fish in the Hocking River.

The stormwater wetland would benefit from continued research. Researching the sediment composition and the pollutants found in the sediment would give a better idea of why no plants are growing in SW2. A study of the sediment would also provide more confidence in removing built up sedimentation. A study of the birds, amphibians, crayfish, algae and plants living within the wetland would also be beneficial. Further study of biological communities would give more information for about the wetlands current ecological functions and give more material for the museum to use for community education.

With the information collected from this project a variety of materials have been developed and offered to the AHA! A Hands-on Adventure Children's Museum. Seen in Appendix B-D two poster formats giving information about the species found were created. Appendix B represents mammals, fish, insects, birds, amphibians, and plants that could be found in the city. Appendix C is an example poster that dives further into the facts of a green sunfish. This animal was chosen for the example as it is the most common animal found in the wetland sites. Information can be altered to highlight information that the museum could best utilize.

Appendix D is a visual of a web/phone application that can be used to dive further into multiple kinds of flora and fauna within Lancaster, Ohio. With funding, this information has also been developed into a protype for a phone or online app within Adobe XD giving information on the species living in different areas within Lancaster, Ohio. If this web app was formally developed and created, community members could access this app on their phones or could be on tablets supplied by the museum.

If this educational option were utilized and fully created, it would be the most expensive option for the museum but could also be formatted into a pamphlet of common species found near the museum for those without smartphone access. Finally, Appendix E is an altered version of Appendix B. Appendix E is formatted to be a trail sign that can be placed by the wetland so that the museum has an object to engage children and parents on their land. With a small grant, a turbidity tube, Myron Ultrameter and kick nets could be obtained by the museum and used for community science projects during the summer.

References

ABOUT. (2015). AHA! A Hands-On Adventure, A Children's Museum. http://www.aha4kids.org/about

Anim, D. O., Fletcher, T. D., Pasternack, G. B., Vietz, G. J., Duncan, H. P., & Burns, M. J. (2019). Can catchment-scale urban stormwater management measures benefit the stream hydraulic environment? *Journal of Environmental Management*, *233*, 1–11. https://doi.org/10.1016/j.jenvman.2018.12.023

Behar, S. (1997). Testing the Waters: Chemical and Physical Vital Signs of a River. *Montpeliet, VT: River Watch Network*.

Beitinger, T. L., Bennett, W. A., & McCauley, R. W. (2000). Temperature Tolerances of North American Freshwater Fishes Exposed to Dynamic Changes in Temperature. *Environmental Biology of Fishes*, *58*(3), 237–275. https://doi.org/10.1023/A:1007676325825

Burgmer, T., Hillebarnd, H., & Pfenninger, M. (2007). Effects of Climate-Driven Temperature Changes on the Diversity of Freshwater Macroinvertebrates. *Oecologia*, *151*, 93–103. https://doi.org/10.1007/s00442-006-0542-9

Chaichana, R., Leah, R., & Moss, B. (2011a). Conservation of pond systems: A case study of intractability, Brown Moss, UK. *Hydrobiologia*, *664*(1), 17–33. https://doi.org/10.1007/s10750-010-0579-y

Chaichana, R., Leah, R., & Moss, B. (2011b). Conservation of pond systems: A case study of intractability, Brown Moss, UK. *Hydrobiologia*, *664*(1), 17–33. https://doi.org/10.1007/s10750-010-0579-y

Chang, F.-H., Lawrence, J. E., Rios-Touma, B., & Resh, V. H. (2013). *Tolerance Values of Benthic Macroinvertebrates for Stream Biomonitoring: Assessment of Assumptions Underlying Scoring Systems Worldwide*. *186*, 2135–2149. https://doi.org/10.1007/s10661-013-3523-6

Collas, F. P. L., van Iersel, W. K., Straatsma, M. W., Buijse, A. D., & Leuven, R. S. E. W. (2019). Sub-Daily Temperature Heterogeneity in a Side Channel and the Influence on Habitat Suitability of Freshwater Fish. *Remote Sensing*, *11*(2367). https://doi.org/10.3390/rs11202367

Dube, L. (1998). The Typologies of Cognitive Dissonance and the Self-Guided Adult Visitor: Assessing Interpretive Aids in a Fine Arts Museum. *Concodia University, Montreal, Quebec, Canada*.

Ebersole, J. L., Liss, W. J., & Frissell, C. A. (2003). Cold water patches in warm streams: Physicochemical characteristics and the influence of shading. *Journal of the American Water Resources Association*, *39*(2), 355–368.

Elosegi, A., Díez, J., & Mutz, M. (2010). Effects of hydromorphological integrity on biodiversity and functioning of river ecosystems. *Hydrobiologia*, *657*(1), 199–215. https://doi.org/10.1007/s10750-009-0083-4

Endreny, A. H. (2010). Urban 5th Graders Conceptions during a Place-Based Inquiry Unit on Watersheds. *Journal of Research in Science Teaching*, *47*(5), 501–517. https://doi.org/10.1002/tea.20348

Engel, F., & Fischer, H. (2017). Effect of Thermal Stratification on Phytoplankton and Nutrient Dynamics in a Regulated River (Saar, Germany). *River Research and Applications*, *33*(1), 135–146. https://doi.org/10.1002/rra.3071

Fairfield County Comprehensive Land Use Plan. (2018). Fairfield County Regional Planning Commission.

Fritz, K. M., Johnson, B. R., & Walters, D. M. (2008). Physical indicators of hydrologic permanence in forested headwater streams. *Journal of the North American Benthological Society*, *27*(3), 690–704. https://doi.org/10.1899/07-117.1

Gavioli, A., Milardi, M., Lanzoni, M., Mantovani, S., Aschonitis, V., Soana, E., Fano, E. A., & Castaldelli, G. (2018). Managing the environment in a pinch: Red swamp crayfish tells a cautionary tale of ecosystem based management in northeastern Italy. *Ecological Engineering*, *120*, 546–553. https://doi.org/10.1016/j.ecoleng.2018.07.013

Grabarkiewicz, J., & Davis, W. (2008). *An introduction to freshwater fishes as biological indicators* (EPA-260-R-08-016). U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC. http://www.epa.gov/bioindicators/html/publications.html

Grung, M., Petersen, K., Fjeld, E., Allan, I., Christensen, J. H., Malmqvist, L. M. V., Meland, S., & Ranneklev, S. (2016). PAH related effects on fish in sedimentation ponds for road runoff and potential transfer of PAHs from sediment to biota. *Science of The Total Environment*, *566–567*, 1309–1317. https://doi.org/10.1016/j.scitotenv.2016.05.191

Haase, D. (2009). Effects of urbanisation on the water balance – A long-term trajectory. *Environmental Impact Assessment Review*, *29*(4), 211–219. https://doi.org/10.1016/j.eiar.2009.01.002

Halliwell, D. B., Langdon, R. W., Daniels, R. A., Kurtenbach, J. P., & Jacobson, R. A. (1999). *Classification of freshwater fish species of the northeastern United States for use in the development of indices of biological integrity, with regional applications* (pp. 301–337). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, CRC Press, Boca Raton, Florida.

Harris, T. L., & Lawrence, T. M. (1978). *Environmental Requirements and pollution Tolerance of Trichoptera* (EPA-600/4-78-063; pp. 1–318). United States Environmental Protection Agency, Environmental Monitoring and Support Laboratory Office of Research and Development, Cincinnati, Ohio. https://nepis.epa.gov/Exe/ZyPDF.cgi/91019ZU4.PDF?Dockey=91019ZU4.PDF

Hausman, C. E., Kershner, M. W., De Szalay, F. A., & Fraser, L. H. (2007). Plant community establishment in a restored wetland: Effects of soil removal. *Applied Vegetation Science*, *10*(3), 383–390.

Hill, B. H., Kolka, R. K., McCormick, F. H., & Starry, M. A. (2014). A synoptic survey of ecosystem services from headwater catchments in the United States. *Ecosystem Services*, *7*, 106–115. https://doi.org/10.1016/j.ecoser.2013.12.004

Hocking Conservancy District | Hocking River | Watershed. (2012). [Government]. Hocking Conservancy District: Margaret Creek Subdistict. http://www.hockingcd.org/hocking/watershed/

Hocking River Stream Restoration & Wetland | Lancaster, OH - Official Website. (n.d.). Retrieved March 20, 2020, from https://www.ci.lancaster.oh.us/562/Hocking-River-Stream-Restoration-Wetland

Hogg, I. D., Williams, D. D., Eadie, J. M., & Butt, S. A. (1995). *The Consequences of Global Warming for Stream Invertebrates: A Field Simulation*. *20*(1/2), 199–206.

Howarth, R., Swaney, D., Butler, T., & Marino, R. (2000). Climatic Control on Eutrophication of the Hudson River Estuary. *Ecosystems*, *3*(2), 210–215. https://doi.org/10.1007/s100210000020

Ivanovsky, A., Belles, A., Criquet, J., Dumoulin, D., Noble, P., Alary, C., & Billon, G. (2018). Assessment of the treatment efficiency of an urban stormwater pond and its impact on the natural downstream watercourse. *Journal of Environmental Management*, *226*, 120–130. https://doi.org/10.1016/j.jenvman.2018.08.015

Jester, D. E., Echelle, A. A., Matthews, W. J., Pigg, J., Scott, C. M., & Collins, K. D. (1992). The fishes of Oklahoma, their gross habitats, and their tolerance of degradation in water quality and habitat. *Proceedings of the Oklahoma Academy of Science*, *72*, 7–19.

Johnson, K. S. (2007). *Field and Laboratory Methods for using the MAIS (Macroinvertebrate Aggregated Index for Streams) in Rapid Bioassessment of Ohio Streams*. 19.

Jordan, T. E., Whigham, D. F., Hofmockel, K. H., & Pittek, M. A. (2003). Nutrient and Sediment Removal by a Restored Wetland Receiving Agricultural Runoff. *Journal of Environmental Quality*, *32*(4), 1534–1547.

Junk, W. J., Bayley, P. B., & Sparks, R. E. (1989). The Flood Pulse Concept in River-Floodplain Systems. *Max Planck Institut Lur Limnologie*, *2*(165), 18.

Karr, J. R., Fausch, K. D., Angermeier, P. L., Yant, P. R., & Schlosser, I. J. (1986). Assessing Biological Integrity in Running Waters A Method and Its Rationale. *Illinois Natural History Survey*, *5*. https://doi.org/554353

Klimkowska, A., Van Diggelen, R., Bakker, J. P., & Grootjans, A. P. (2007). Wet meadow restoration in Western Europe: A quantitative assessment of the effectiveness of several techniques. *Biological Conservation*, *140*(3), 318–328.

Kurylyk, B. L., MacQuarrie, K. T. B., Linnnansaari, T., Cunjak, R. A., & Curry, R. A. (2015). Preserving, augmenting, and creating cold-water thermal refugia in rivers: Concepts derived from research on the Miramichi River, New Brunswick (Canada). *Ecohydrology*, *8*(6), 1095–1108. https://doi.org/10.1002/eco.1566

Lowe, W. H., & Likens, G. E. (2005). Moving Headwater Streams to the Head of the Class. *BioScience*, *55*(3), 196. https://doi.org/10.1641/0006-3568(2005)055[0196:MHSTTH]2.0.CO;2

Mack, J. J., & Micacchion, M. (2007). *An ecological and functional assessment of urban wetlands in central Ohio. Volume 1: Condition of urban wetlands using rapid (level 2) and intensive (level 3) assessment methods.* [Ohio EPA Technical Report WET/2007-3A]. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio. http://www.epa.state.oh.us/dsw/wetlands/WetlandEcologySection_reports.html

Mack, John J. (2001). *Ohio Rapid Assessment Method for Wetlands, Manual for Using Version 5.0. Ohio EPA Technical Bulletin Wetland/2001-1-1*. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, Ohio. http://www.epa.ohio.gov/dsw/401/index.aspx

Matamoros, V., Arias, C. A., Nyugen, L. X., Salvadó, V., & Brix, H. (2012). *Occurrence and behavior of emerging contaminants in surface water and a restored wetland*. *88*(9), 1083–1089.

McNeil, V. H., & Cox, M. E. (2000). Relationship between conductivityand analysed composition in a large set of natural surface-water samples, Queensland, Australia. *Environmental Geology*, *39*(12), 1325–1333.

Meyer, J. L., Kaplan, L. A., Newbold, D., Strayer, D. L., Woltemade, C. J., Zedler, J. B., Beilfuss, R., & Carpenter, Q. (2003). *The Scientific Imperative for Defending Small Streams and Wetlands*. 1–24.

OAC Chapter 3745-2. (2014). In *State of Ohio Water Quality Standards*. https://www.epa.ohio.gov/portals/35/rules/01_all.pdf

Ohio EPA. (1991a). Biological and water Quality Study of the Hocking river Mainstem and Selected Tributaries. *Ecological Assessment Section Division of Water Quality Planning & Assessment*.

Ohio EPA. (1991b). *Biological and Water Quality Study of the Hocking River Mainstream and Selected Tributaries*. State of Ohio Environmental Protection Agency.

Ohio EPA. (2001). Ohio Rapid Assessment Method for Wetlands 10 Page Form for Wetland Categorization. *Division of Surface Water*, 11.

Ohio EPA. (2006). *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (2006-06-1) [OHIO EPA Technical Bulletin EAS]. State of Ohio Environmental Protection Agency Division of Surface Water Ecological Assessment Section.

Ohio EPA. (2009a). *Total Maximum Daily Loads for the Hocking River Watershed*. State of Ohio Environmental Protection Agency Division of Surface Water.

Ohio EPA. (2009b). Hocking River Watershed TMDL Report. *State of Ohio Environmental Protection Agency*. http://www.epa.ohio.gov/dsw/tmdl/HockingRiverTMDL.aspx

Ohio EPA. (2015). *Biological Criteria for the Protection of Aquatic Life: Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities* (Vol. 3). Division of Surface Water Ecological Assessment Section.

Ohio EPA. (2019). *Ohio EPA Macroinvertebrate Taxa List* (pp. 1–27). Ohio Environmental Protection Agency. https://www.epa.ohio.gov/Portals/35/bioassess/MasterTaxaList_123119.pdf?ver=2020-01-07-095148-517

Peng, Z., Jinyan, K., Wenbin, P., Xin, Z., & Yuanbin, C. (2018). Effects of Low-Impact Development on Urban Rainfall Runoff under Different Rainfall Characteristics.

Polish Journal of Environmental Studies, *28*(2), 771–783. https://doi.org/10.15244/pjoes/85348

Pirhalla, D. E. (2004). Evaluating fish-habitat relationships for refining regional indexes of biotic integrity: Development of a tolerance index of habitat degradation for Maryland stream fishes. *Transactions of the American Fisheries Society*, *133*, 144–159.

Pollock, M. S., Clarke, L. M. J., & Dubé, M. G. (2007). The Effects of Hypoxia on Fishes: From Ecological Relevance to Physiological Effects. *NRC Research Press*, *15*. https://doi.org/10.1139/A06-006

Pullanikkatil, D., Palamuleni, L., & Ruhiiga, T. (2015). Impact of land use on water quality in the Likangala catchment, southern Malawi. *African Journal of Aquatic Science*, *40*(3), 277–286. https://doi.org/10.2989/16085914.2015.1077777

Pullanikkatil, D., Palamuleni, L., & Ruhiiga, T. (2016). Assessment of land use change in Likangala River catchment, Malawi: A remote sensing and DPSIR approach. *Applied Geography*, *71*, 9–23. https://doi.org/10.1016/j.apgeog.2016.04.005

Ramsar Convention Secretariat. (2010). *Water-Related Guidance: An Integrated Framework for the Convention's Water-Related Guidance* (Vol. 8). Ramsar Convention Secretariat.

Sabet, M. (2018). Current Trends and Tensions in Outdoor Education. *BU Journal of Graduate Studies in Education*, *10*(1).

Serrell, B. (1996). *Exhibit Labels: An Interpretive Approach*. Rowman Altamira.

Skagen, S. K., Melcher, C. P., & Haukos, D. A. (2008). Reducing Sedimentation of Depressional wetlands in agricultural landscapes. *Wetlands*, *28*(3), 594–604.

Sorensen, D. L., McCarthy, M. M., Middlebrooks, E. J., & Porcella, D. B. (1977). *Suspended and Dissolved Solids Effects on Freshwater Biota*. Corvallis Environmental Research Laboratory.

Stoffels, R. J., Clarke, K. R., Rehwinkel, R. A., & McCarthy, B. J. (2014). Response of a floodplain fish community to river-floodplain connectivity: Natural versus managed reconnection. *Canadian Journal of Fisheries and Aquatic Sciences*, *71*(2), 236–245. https://doi.org/10.1139/cjfas-2013-0042

StreamStats. (n.d.). [Government]. USGS StreamStats. Retrieved April 10, 2019, from https://streamstats.usgs.gov/ss/

Taft, R. A., & Jones, C. (n.d.). *User's Manual and Scoring Forms*. 72.

Taylor, G. D., Fletcher, T. D., Wong, T. H. F., Breen, P. F., & Duncan, H. P. (2005). Nitrogen composition in urban runoff—Implications for stormwater management. *Water Research*, *39*(10), 1982–1989. https://doi.org/10.1016/j.watres.2005.03.022

Thomaz, S. M., Bini, L. M., & Bozelli, R. L. (2007). Floods increase similarity among aquatic habitats in river-floodplain systems. *Hydrobiologia*, *579*(1), 1–13. https://doi.org/10.1007/s10750-006-0285-y

Tilden, F. (1957). *Interpreting Our Heritage: Principles and Practices for Visitor Services in Parks, Museums, and Historic Places*. University of North Carolina Press.

Tornwall, B., Sokol, E., Skelton, J., & Brown, B. L. (2015). Trends in Stream Biodiversity Research since the River Continuum Concept. *Diversity*, *7*, 16–35. https://doi.org/10.3390/d7010016

U.S. EPA (Environmental Protection Agency). (2011). *A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams* (EPA/600/R-10/023F; pp. 1–276). Office of Research and Development, National Center for Environmental Assessment.

USDA. (2008). *Hydrogeomorphic Wetland Classification System: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service* (pp. 1–10) [Technical Note No. 190–8–76]. United States Department of Agriculture, Natural Resources Conservation Service. https://biosurvey.ku.edu/sites/biosurvey.ku.edu/files/docs/cpcb/workgroups/nutrient/hydrogeo.pdf

Utah State University Extension. (2016). Turbidity Tube Conversion Chart. https://extension.usu.edu/utahwaterwatch/monitoring/field-instructions/turbidity/turbiditytube/turbiditytubeconversionchart

van Vliet, M. T. H., Franssen, W. H. P., Yearsley, J. R., Ludwig, F., Haddeland, I., Lettenmaier, D. P., & Kabat, P. (2012). Global River Discharge and Water Temperature Under Climate Change. *Global Environmental Change*, *23*, 450–464.

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). *The River Continuum Concept*. *37*, 130–137.

Vrebos, D., Beauchard, O., & Meire, P. (2017). The Impact of Land Use and Spatial Mediated Processes on the Water Qualtity in a River System. *Science of The Total Environment*, *601–602*, 365–373.

Walton, N. R. G. (1989). Electrical Conductivity and Total Dissolved Solids-What is Their Precise Relationship? *Desalination*, *72*, 275–292.

Wandersee, J. H., & Clary, R. M. (2007). Learning on the Trail: A Context Analysis of a University Arboretum's Exemplary Interpretive Science Signage System. *The American Biology Teacher*, *69*(1).

What Does Universal Design Look Like? (2011). *Museum Magazine: American Alliance of Museums*, *March/April 2011*. http://ww2.aam-us.org/docs/default-source/museum/going-beyond-what-does-universal-design-look-like.pdf?sfvrsn=0

Yoder, C. O., & Rankin, E. T. (1998). The Role of Biological Indicators in a State Water Quality Management Process. *Environmental Monitoring Assessment*, *51*(1–2), 61–88.

Zhang, H., & Lai Lei, S. (2012). A structural model of residents' intention to participate in ecotourism: The case of a wetland community. *Tourism Management*, *33*, 916–925. https://doi.org/10.1016/j.tourman.2011.09.012

Appendix A

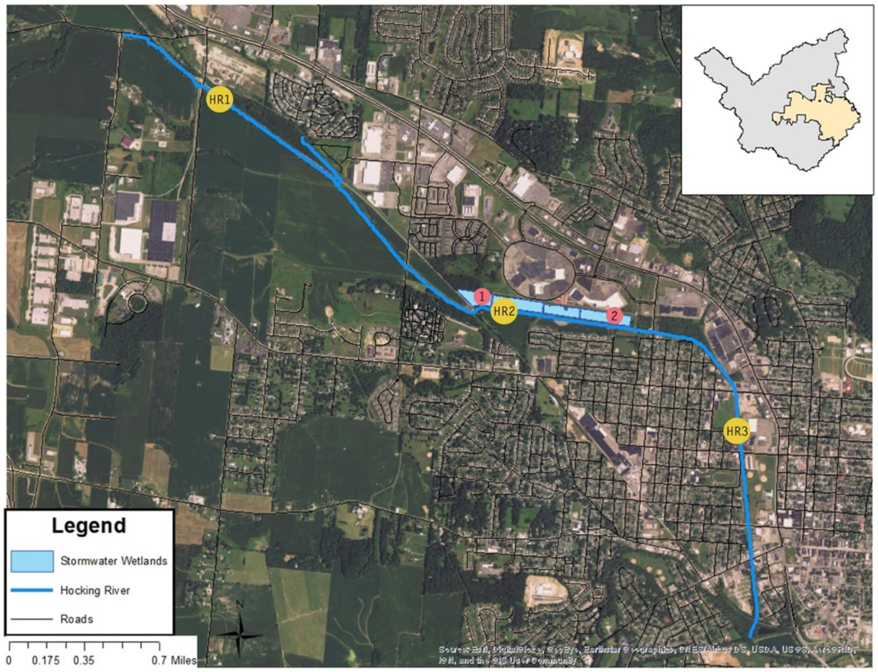
Stakeholder Executive Summary

Upper Hocking River Characterization Project

The headwaters portion of the Hocking River that runs through Lancaster, Ohio, has not been studied by the Ohio EPA since 2004. In 2008 the City of Lancaster added inlet structures that connect the Hocking River to a flood storage basin, creating the Hocking River Stream Restoration & Wetland. Since this event, the storage basin has acted as both a storage basin and a wetland. There had not been a study of this basin/wetland since the structures were constructed; this 2018-2019 study has been able to quantify the current conditions of the stream and wetland habitat and aquatic biology. The habitat and biological information collected will be able to assist with community recreation and education in the area.

Between June and November 2019, data was collected on habitat quality, fish, insects, and water chemistry. The Hocking River and the wetland were sampled at five locations. Wetland locations were sampled behind the AHA! Children's Museum and behind Target. The headwaters of the Hocking River in Lancaster were sampled upstream from the wetland, adjacent to the wetland, and downstream from the wetland. These sites can be seen in Figure 1.

Figure 1: Map of Sampling Sites



Note. Yellow dots indicate where the Hocking River sampling sites are located. Red dots indicate the two wetland sites that were sampled.

Habitat quality was assessed based on the Quality Habitat Evaluation Index and Ohio Rapid Assessment Method for Wetlands version 5.0, as recommended by the Ohio EPA, and results can be found in Table 1. Sites in the Hocking River upstream and adjacent to the wetland are both "Good" quality habitats, while downstream from the wetland is "Poor" quality habitat. The wetland near the AHA! Children's Museum is a "Good" condition wetland that supports biodiversity but is slightly degraded. The wetland behind Target is a "Poor" quality wetland and is highly degraded. The wetland behind the AHA! Museum shows promise to support good habitat for animals and recreation, while the wetland behind Target would need restoration alterations to support a better habitat.

During this study, fish and macroinvertebrates were collected and identified in the three Hocking River locations and in the wetland closest to the AHA! Children's Museum. All the riverine sites received a fish IBI (Index of Biotic Integrity) score that indicated that fish species are "Good". The wetland does not have a scoring system like the IBI; however, of the 128 fish collected, 110 were green sunfish (85%), which is a very tolerant species. This indicated that the wetland fish diversity is low and not of the highest quality. The river supported more fish and also more species diversity than the wetland. Fish indices have improved since 2004 in the river sites. In 2004, upstream from the wetland, fish IBI was 42 and downstream from the wetland the IBI was 32 on a scale of 12 to 60. Now, as seen in Table 1, upstream from the wetland has improved, the IBI is 44, and downstream from the wetland the IBI is 40.

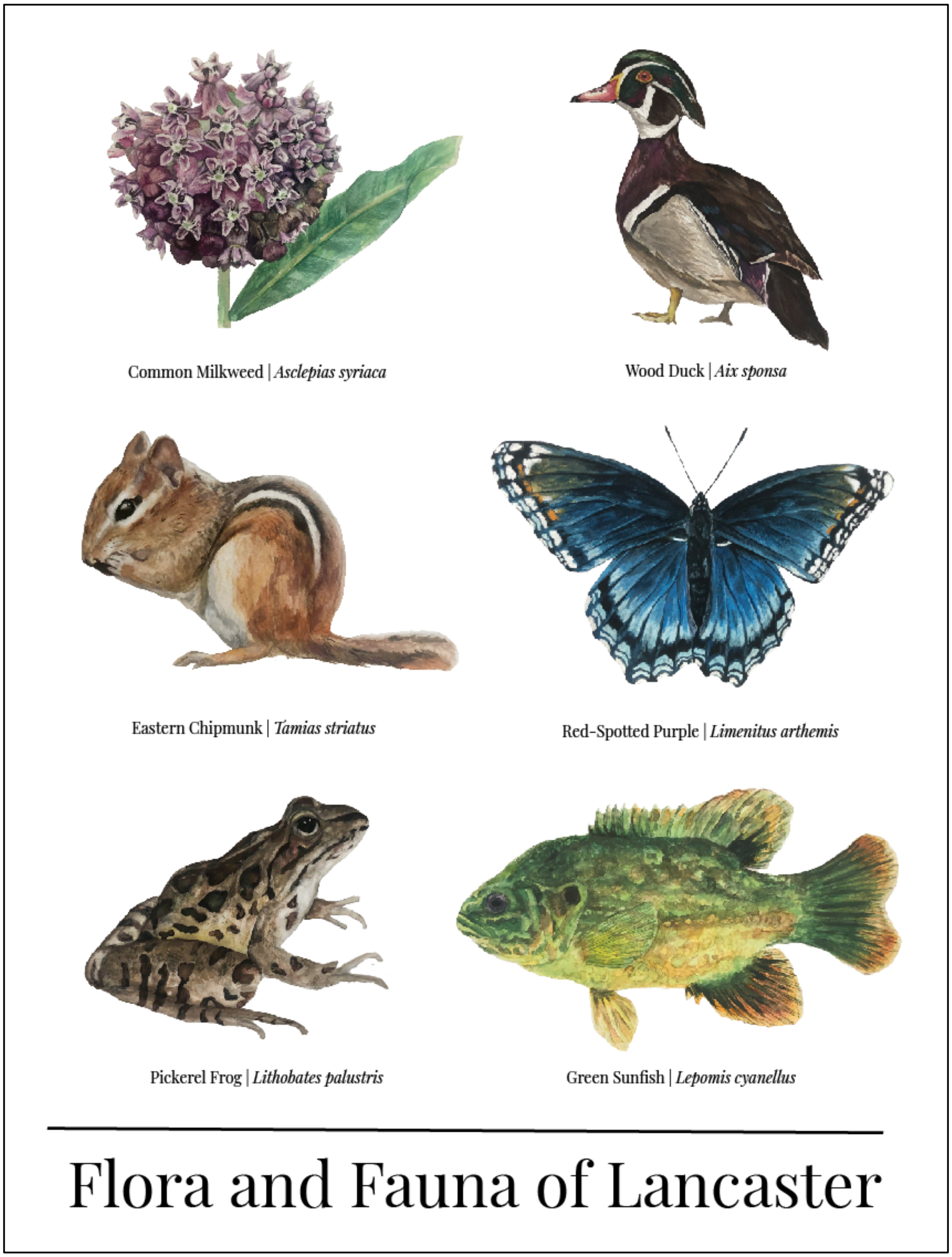
Table 1: Summary of habitat quality indicator scores

	Water Quality Score	Fish IBI Score	Macroinvertebrate Score
HR1	66.5 / 100	44 / 60	x
HR2	66.0 / 100	x	11 / 18
HR3	36.5 / 100	40 / 60	13 /18
SW1	35.5 / 100	Modified Category 2	
SW2	20.0 / 100	Category 1	

Overall, all reaches of the Hocking River that were sampled and the wetland behind the AHA! Museum would be good candidates for enhanced community education and recreation. To improve the wetland health for outdoor recreation and public education there are a few steps that could be taken. Temperatures in the wetlands were high during the summer and could cause fish die offs. More vegetation in and around the river and wetland would help introduce shade to cool the water down and establish more habitat for aquatic species. Adding another connection or two into the wetland from the river would also assist in cooling the water and allow for aquatic animals to pass between the two water bodies. By improving water quality, these recommendations would also increase biological diversity and the number of sensitive animals in the wetland.

Appendix B:

Flora and Fauna Poster



Appendix C:

Green Sunfish Example Poster

Green Sunfish

Lepomis cyanellus

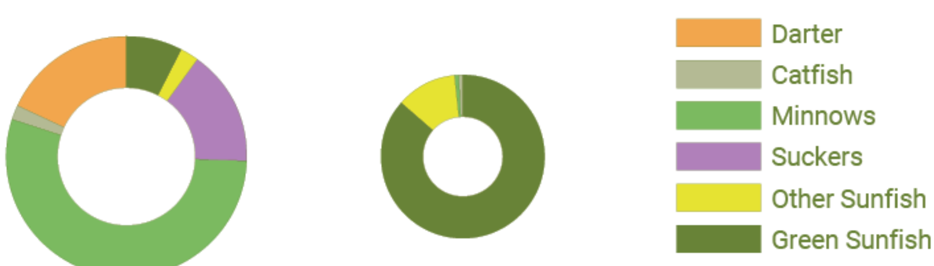
The green sunfish is found through out the Hocking River and is also the most common fish found in the Lancaster Stream and Restoration wetland behind the River Valley Mall.

Description
Dark olive-green, pectoral fins short and rounded. Black spot often near back of dorsal fin. Opercle (earflap) has a black spot and is sometimes thin with a white to yellow margin. Usually 3-7 inches, can be up to 10 inches.

Reproduction
Green sunfish spawn from mid-May to August. You can find nest the males have built in shallow water.

Habitat
These fish can live almost anywhere. They are native to ohio and found all over the state. Often times they hide in areas with rocks, logs or brush piles.

Personality
They are very Aggressive, easily cought on fishing line and will eat about anything! Think carnivores or insectivores, in Lancaster they might eat crayfish or snails.



Hocking River Fish

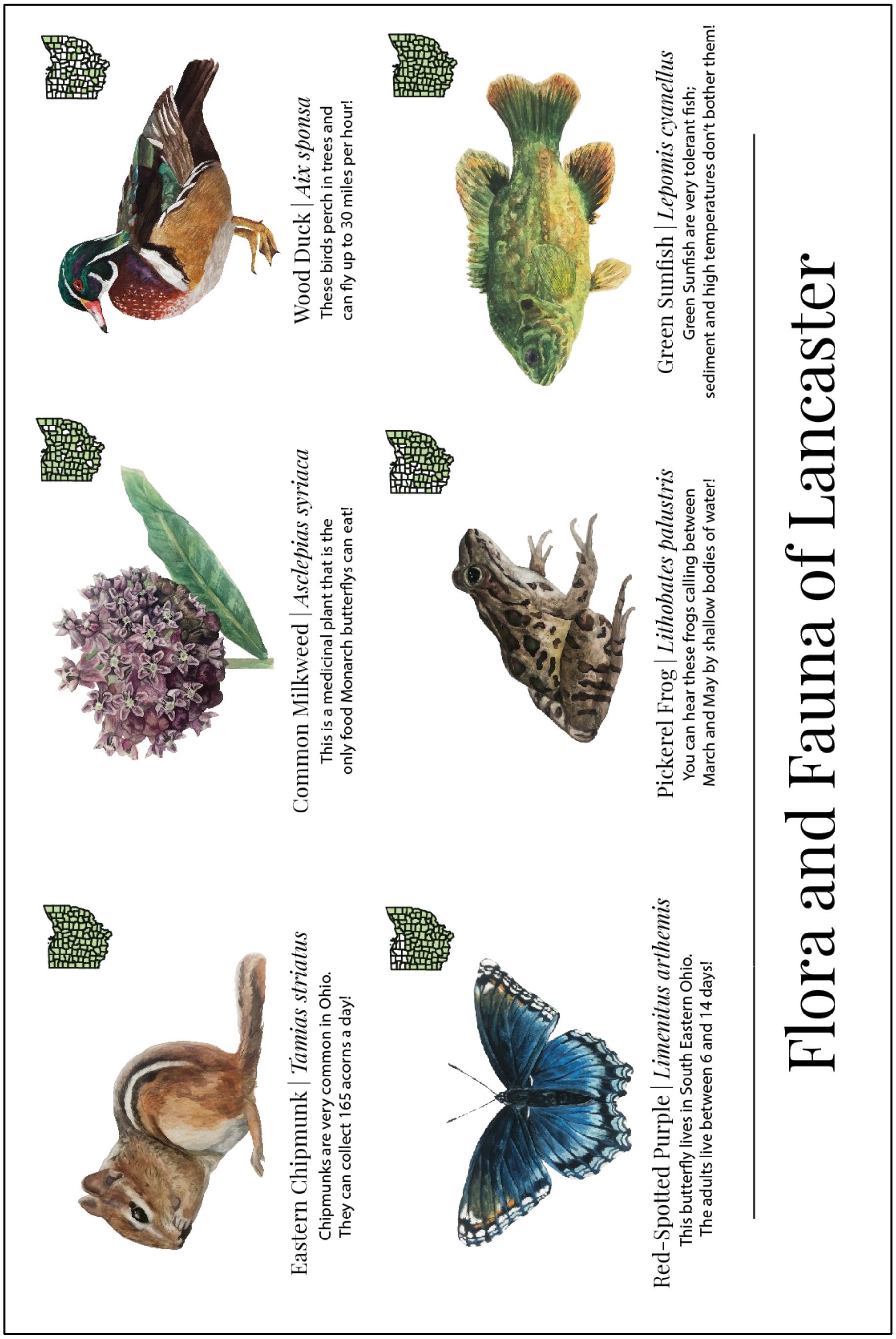
Stream Restoration Wetland Fish

Appendix D:

Still of Web/Phone Application

Appendix E:

Lancaster Trail Signage



Appendix F:

Water Quality Data

Locat.	Date	pH	Temp (oC)	ORP (mV)	Tds (ppm)	Conductivity (µS/cm)	DO (mg/L)	Clarity (cm)	TSS (mg/L)	Time
HR1	6/21/19	6.39	19.4	140.0	266.0	398.1	7.49	22.9	31.11	11:27
HR1	6/28/19	5.83	20.9	135.0	370.2	546.8	8.06	25.1	11.16	9:55
HR1	7/18/19	6.96	23.1	153.0	253.1	378.7	7.85	4.0	58.60	11:22
HR1	8/6/19	7.06	22.7	164.0	384.3	567.1	7.93	64.4	5.58	10:45
HR1	8/21/19	7.33	23.0	184.0	400.6	589.2	7.68	48.0	4.33	10:33
HR1	9/7/19	8.54	20.3	37.0	396.3	582.5	8.80	47.0	2.78	3:10
HR1	9/20/19	8.22	21.2	170.0	197.0	616.6	8.40	59.7	11.44	4:39
HR1	10/9/19	8.41	15.1	83.0	407.6	599.2	9.57	160.0	2.00	
HR1	10/23/19	8.03	12.8	106.0	418.1	614.0	9.72	120.0	2.56	2:30
HR1	11/8/19	8.33	4.7	113.0	432.3	634.3	13.15	72.4	6.33	3:26
HR1	11/19/19	8.07	5.5	137.0	459.3	672.3	12.81	65.0	3.44	11:29
HR2	6/21/19	7.80	20.3	101.0	239.4	257.3	7.83	8.2	78.00	12:33
HR2	6/28/19	8.45	21.8	77.0	392.0	578.6	8.55	20.3	10.26	10:31
HR2	7/18/19	7.95	24.6	66.0	338.3	501.2	8.56	5.6	61.85	12:14
HR2	8/6/19	8.08	23.6	51.0	436.7	638.5	8.48	52.4	9.08	11:40
HR2	8/21/19	8.03	23.0	78.0	471.9	692.6	7.54	31.0	20.78	11:18
HR2	9/7/19	8.39	22.1	75.0	498.8	729.2	10.92	34.2	10.11	3:45
HR2	9/20/19	8.20	23.9	148.0	499.5	728.5	12.97	49.3	5.89	4:15
HR2	10/9/19	8.57	18.1	25.0	513.6	748.5	12.67	100.2	6.33	
HR2	10/23/19	8.24	13.9	101.0	461.0	675.3	14.42	54.8	2.33	3:09
HR2	11/8/19	8.23	8.0	110.0	461.5	676.7	14.47	87.6	4.44	3:05
HR2	11/19/19	8.09	7.7	114.0	516.2	753.2	14.07	59.8	9.44	
HR3	6/21/19	8.37	22.1	81.0	248.0	368.7	7.84	10.1	78.11	1:52
HR3	6/28/19	8.73	22.3	62.0	396.7	583.1	7.89	26.2	27.66	11:00
HR3	7/18/19	8.10	24.5	67.0	333.6	494.3	7.33	6.6	44.40	1:00
HR3	8/6/19	7.83	23.2	96.0	475.8	691.2	7.50	34.4	9.61	1:07
HR3	8/21/19	7.95	22.6	83.0	518.8	757.0	6.66	37.4	23.78	12:15
HR3	9/7/19	8.38	22.1	73.0	502.2	733.9	8.38	34.0	10.33	5:00
HR3	9/20/19	8.10	22.3	182.0	535.5	779.4	9.81	59.0	4.78	5:04
HR3	10/9/19	8.56	16.9	54.0	504.8	736.9	10.07	78.8	6.33	5:10
HR3	10/23/19	8.13	14.6	106.0	491.4	718.7	10.80	75.0	6.33	4:03

HR3	11/8/19	8.52	7.3	127.0	437.5	641.6	13.14	45.4	14.56	2:12
HR3	11/19/19	8.11	8.0	85.0	527.0	767.9	12.09	33.4	11.11	
SW1	6/21/19	7.52	24.4	61.0	256.4	382.8	4.42	35.3	31.64	12:02
SW1	6/28/19	7.20	25.0	97.0	386.2	570.4	5.25	45.0	3.63	11:30
SW1	7/18/19	7.57	26.4	50.0	344.1	511.9	2.10	59.8	6.00	11:50
SW1	8/6/19	7.37	26.2	81.0	494.7	739.2	2.73	43.2	14.43	11:18
SW1	8/21/19	7.54	25.3	86.0	500.4	730.2	1.36	38.8	22.56	11:04
SW1	9/7/19	8.01	44.5	35.0	433.6	636.2	5.06	23.4	11.56	3:30
SW1	9/20/19	7.60	29.7	142.0	535.6	775.1	13.40	16.1	36.56	4:07
SW1	10/9/19	8.74	18.1	70.0	215.7	325.1	6.70	26.5	19.11	
SW1	10/23/19	8.07	16.0	104.0	388.2	572.9	11.43	42.6	23.89	3:00
SW1	11/8/19	8.40	8.5	117.0	251.3	374.7	9.20	29.2	25.33	2:54
SW1	11/19/19	7.93	6.7	124.0	436.1	639.8	8.37	21.8	4.44	12:17
SW2	6/21/19	7.53	25.8	98.0	160.9	245.9	4.42	35.3	79.11	1:02
SW2	6/28/19	7.97	29.7	62.0	190.4	289.5	8.24	12.0	35.83	11:55
SW2	7/18/19	8.22	34.3	45.0	266.8	399.7	11.74	13.2	141.00	12:39
SW2	8/6/19	7.83	34.7	95.0	318.4	478.2	11.87	14.0	51.89	12:30
SW2	8/21/19	8.26	29.2	84.0	292.1	435.8	9.71	8.9	68.00	11:40
SW2	9/7/19	8.72	30.1	58.0	246.9	372.0	11.23	12.0	51.78	4:00
SW2	9/20/19	7.85	34.7	117.0	304.1	453.1	18.96	8.4	66.67	3:35
SW2	10/9/19	9.39	26.7	30.0	248.7	371.7	13.69	10.4	55.78	4:57
SW2	10/23/19	8.78	21.5	95.0	245.2	366.8	12.50	11.4	57.56	3:27
SW2	11/8/19	8.58	13.2	120.0	215.2	323.9	15.60	12.8	45.89	2:36
SW2	11/19/19	8.38	9.1	95.0	251.4	376.1	12.54	7.6	55.44	