Effectiveness of Glen Helen Protected Land Policies and Efforts in Preserving its Aquatic

Habitats

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Abstract

Aquatic invertebrates are known to be effective bioindicators of water quality. The Yellow Springs Creek (Yellow Springs, Ohio) has previously been listed as an excellent warmwater habitat for aquatic invertebrates, thus indicating the stream has healthy aquatic habitats and high water quality. However, the data used to make that classification was collected in 1998. Since 1998, Greene County, Ohio has experienced shifts in land use that has increased agricultural inputs to many local aquatic ecosystems. To properly assess the effectiveness of the Glen Helen's conservation efforts in protecting and enhancing aquatic habitats, new data needs to be collected. I will survey aquatic invertebrates from three separate locations - one upstream of the Glen Helen, one within the Glen Helen, and one downstream of the Glen Helen - in order to update the data and test for statistically significant (α<0.05) differences in aquatic invertebrate richness and abundance. I will also collect water quality measurements and characterize the physical parameters of our sampling sites at the time of my surveys. Collected data will be analyzed using the Ohio Environmental Protection Agency's standardized Invertebrate Community Index (ICI) and Qualitative Habitat Evaluation Index (QHEI). This updated data on the Glen Helen preserve and surrounding areas will allow me to reevaluate the health of the Yellow Springs Creek and the effectiveness of the preserve's existing conservation efforts aimed to improve their aquatic ecosystem. Variance in abundances of certain invertebrates in the different testing sites will help to indicate potential pollutants, specifically agricultural fertilizers such as nitrogen and phosphorus. Results would likely be of interest to Antioch College due to the potential educational and promotional opportunities such as collecting similar annual data and promoting the school's conservation work. Additionally, if the Glen Helen's practices are

effective at conserving aquatic habitats, other conservation sites may find success using similar methods.

Introduction

The Yellow Springs Creek (Yellow Springs, Ohio) runs through the 1000 acre Glen Helen nature preserve and has been ranked as an excellent warmwater habitat for aquatic vertebrates and invertebrates (Ohio Environmental Protection Agency, 2002). Many aquatic invertebrates act as indicator species and the comparative analysis of their biodiversity in the creek can indicate the overall health of the Glen Helen (Fierro et al., 2017). The creek was ranked with an "exceptional" Invertebrate Community Index (ICI) score of 50 on a scale of 0 - 60 (Ohio Environmental Protection Agency, 2002, 2015). This score represents high abundances of aquatic invertebrates, which act as stream health indicators and, therefore, are indicative of the good water quality in the creek.

Data used to assign those classifications was collected in 1998, almost two decades ago (Ohio Environmental Protection Agency, 2002, 2015). Consequently, this data is no longer sufficient for assessing the health of aquatic habitats within Yellow Springs Creek because surrounding land use and environmental factors, such as seasonal temperature and rainfall, have changed since 1998 (U.S. Department of Agriculture, 1999, 2012; Pryor et al., 2014). In 1997, the total acreage of farms in Greene County was 178,332, accounting for ~67% of the land in the county (U.S. Department of Commerce, 1997, 2010; Greene County Farmland Preservation Task Force, 2000). The last Census of Agriculture in 2012 showed a decrease of agricultural land use, accounting for only ~55% of the land in Greene County (U.S. Department of Commerce, 2010; U.S. Department of Agriculture, 2012). Agricultural plots upstream of the Glen Helen potentially

alter the health of Yellow Springs Creek through surface runoff and substrate leaching. Therefore, changes in Greene County land use could alter the stream health and potentially change the aquatic vertebrates and invertebrates expected within that habitat, making the 1998 data insufficient for current assessments.

In addition to changes in land use in Greene county, many agricultural technologies have been developed and widely implemented since 1998. For example, Monsanto introduced Roundup Ready soybeans and corn to the market in 1996 and 1998 respectively. The introduction of these crops allowed for the increased application of pesticides, such as glyphosate, without damage crop yields. From 1995 to 2008 the amount of pesticide applied to soybeans, a common crop in Ohio, increased by approximately 40 millions of pounds (Nehring et al., 2014). Herbicide application on soybean crops has also increased since 1998 (Nehring et al., 2014). Additionally, the active ingredients in pesticides and herbicides have changed as well. For example, most insecticides were historically made with Toxaphene and DDT but are now primarily made using Chlorpyrifos and Aldicarb (Nehring et al., 2014). These active ingredients can alter aquatic habitats in very different ways than their predecessors and, thus, the watersheds near agricultural fields may have altered significantly over time. Since data used for assessments of the Glen Helen preserve's health was collected in 1998, the impacts of this increased pesticide application has been undocumented within the Yellow Springs Creek.

I propose an experimental study that surveys the present aquatic invertebrates and invertebrates at three separate sites; 1) in the Glen Helen nature preserve, 2) upstream of Glen Helen, and 3) downstream of Glen Helen. This study design will allow me to test if the Glen Helen's protected status results in a statistically significant difference ($\alpha < 0.05$) in stream health

as indicated by the ICI and IBI. Additionally, I will monitor water quality and assign a Qualitative Habitat Evaluation Index (QHEI) score at each site (Rankin, 1989; Ohio Environmental Protection Agency, 2006). The aim of this study is to provide updated information on the aquatic macroinvertebrates within the Yellow Springs Creek and perform the first comparative study of aquatic fauna within the Glen Helen to evaluate the effectiveness of their practices on preserving aquatic habitats. Results from this study could be useful to future land use decisions, including agricultural land use, and conservation practices of aquatic habitats in the region.

Literature Review

Watershed degradation due to agricultural runoff is one of the more well known links between human activities and environmental destruction (Hodkinson and Jackson, 2005). However, while agricultural runoff is a known source of environmental destruction, the agricultural industry continues to thrive in the United States. The United States occupies more than 330 million acres of agricultural land and, when that land is not properly managed, chemical fertilizers and pesticides can be washed into local watersheds (Environmental Protection Agency, 2005). These statistics are reflected by Greene county, Ohio, in which approximately 55% of the land is being used for agriculture (U.S. Department of Commerce, 2010; U.S. Department of Agriculture, 2012). In 2000, agriculture was the largest contributor to watershed damage and was listed as a source of pollution for 128,859 river and stream miles, which accounts for 48% of all the impaired miles surveyed (Environmental Protection Agency, 2000). This indicates the harmful impact agricultural land can have on local watersheds. Agricultural runoff impacts

include changes in pH, temperature, salinity, suspended solids, and nutrients, which are all detrimental to the abiotic environment and the aquatic organisms within that habitat (Hodkinson and Jackson, 2005; Fierro et al., 2017). As the chemical properties of an aquatic ecosystem changes, less tolerant species may experience population declines. Agricultural runoff including nutrient loads and pesticides have been shown to decrease some fish and invertebrate populations (Cuffney et al., 2000).

Bioindicators have previously been defined as "a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on a habitat, community, or ecosystem, or is indicative of the diversity of a subset of taxa, or of the wholesale diversity, within an area" (McGeoch, 1998; Hodkinson and Jackson, 2005). More specifically, species that indicate dramatic changes in their environments through their abundance allows them to be used as a measure of physical and chemical changes. Additionally, bioindicator species abundance as a result of those changes can be used to indicate the biodiversity and health of an ecosystem. These species are typically less tolerant to chemical and physical changes in their ecosystem, or have a strong reliance on an aspect of their ecosystem and face population declines sooner than more tolerant species acting as a signal to researchers (Kripa et al., 2013). Organisms who have specific environmental tolerances, for example require a narrow range of pH, are able to indicate slight changes in their environment either through their health status or whether or not they are present in an area. Aquatic organisms respond to physical changes as well, such as channelization, which is more challenging to assess using traditional methods such as chemical testing kits (Ruaro et al., 2015).

Since different species have different environmental tolerances, different species and their abundances can be used as indicators for specific changes within an ecosystem. Therefore, many species are used as bioindicators for the large range of potential impacts from agriculture runoff, such as chances in pH or nitrogen content. Fish and macroinvertebrates are the most commonly used indicator organisms in aquatic research (Ruaro et al., 2015). Table 1 lists common pollutants and invertebrate groups that are known bioindicators for those inputs, further demonstrating the diversity in tolerances and highlighting the need to sample several taxa to gain a broader understanding of ecosystem health. While both fishes and invertebrates have been shown to be effective bioindicators, benthic invertebrates are more sensitive to changes in their ecosystem, especially when testing for chemical and physical changes in sediment (Berkman et al, 1986; Ruaro et al., 2015). Due to macroinvertebrates increased sensitivity to some environmental changes and different life cycles compared to fish, benthic macroinvertebrates are the most frequently used bioindicators for aquatic environments (Jehamalar et al., 2010). Sediment pollution, which can be caused by agricultural runoff, is known to reduce macroinvertebrate diversity and alter the ecosystem community composition (Carew et al., 2007). Agricultural practice's wide range of impacts, and the variability in the intensity of such impacts, on nearby watersheds requires researchers to observe a wide range of organisms because using only one bioindicator could result in a misinterpretation of the health of an ecosystem.

Table 1: Common invertebrate groups used as bioindicators depending on pollutant type (Hodkinson and Jackson, 2005).

Chemical/pollutant	Invertebrate group	Reference
Aquatic		
pH/acidification	General lotic invertebrates	Clenaghan and others 1998, Larsen and others 1996
	Lentic invertebrates	Lonergan and Rasmussen 1996
	Lentic chironomids	Mousavi 2002
Nitrogen and phosphorus	Lotic insects with pathogenic microorganisms	Lemly 2000, Lemly and King 2000
	Lentic chironomids	Brodersen and Lindegaard 1997
Heavy metals	Lentic *Chaoborus*	Croteau and others 2002
	Lotic nematodes and ciliates	Fenske and Gunther 2001
	Benthic invertebrates	Grumiaux and others 2000, Nelson 2000, Cain and others 1992
	Caddisflies	Aizawa and others 1994
Organic toxicants	Lotic nematodes and ciliates	Fenske and Gunther 2001
	Cladocera	Baldwin and others 2001, Guilhermino and others 2000
	Benthic invertebrates	Grumiaux and others 2000
Pesticides	Benthic invertebrates	Fulton and Key 2001
	Lentic zooplankton	Kreutzweiser and Faber 1999
	Dragonflies	Takamura and others 1991
Coal mine runoff	Trichoptera	Fernandez-Alaez and others 2002
Terrestrial		
pH/acidification	Soil microarthropods	van Straalen 1998
Heavy/trace metals	Several soil invertebrates	Cortet and others 1999, van Straalen 1998, Dallinger 1994
	Sarcophagid flies	Bartosova and others 1997
Air pollution/ acid deposition	Several invertebrates	Saldiva and Bohm 1998
	Spiders	Horvath and others 2001
	Collembola	Kopeszki 1997, Steiner 1995
	Cryptostigmatic mites	Sterner 1995
	Day flying Lepidoptera	Kozlov and others 1996
Nitrogen inputs	Collembola	Kopeszki 1997
Pesticides	Collembola	Frampton 1997
	Soil microarthropods	Trublayevich and Semenova 1994
	Various soil invertebrates	Cortet and others 1999
Asbestos	Sarcophagid flies	Bartosova and others 1997

Macroinvertebrate assemblages are good bioindicators of ecosystem degradation related to farming, such as increases in nitrogen and phosphorus (Fierro et al., 2017).This is due to their abundance, varying environmental tolerances, and the ability to easily collect a range of organisms representative of the aquatic ecosystems health. There are a number of macroinvertebrates in Ohio that have been listed as good bioindicators. Decapoda (e.g. crayfish) are good bioindicators for pesticides and organic toxicants and Diptera (e.g. flies) are good

bioindicators of nitrogen and phosphorus, both of which inhabitat Ohio (Hodkinson and Jackson, 2005; Ohio Environmental Protection Agency, 2016). Members of Chironomidae can be particularly useful for detecting sediment pollution and shifts in pH that are often caused by agricultural runoff (Orendt, 1999; Carew et al., 2007). Trichoptera (ie. *Ceraclea ancylus*) are some of the most useful bioindicators and are widely used because they have a low tolerance for high sedimentation and nutrient concentrations (Jehamalar et al., 2010). Diptera, the taxonomic order including Chironomidae and Trichoptera have shown decreases in abundance and diversity downstream of runoff sites with increased suspended solids (Azrina et al., 2006). Due to the number of environmental changes agricultural runoff can cause, and the variability in macroinvertebrate tolerances, surveys are most complete when including multiple taxonomic orders of macroinvertebrates.

Methods

I will test habitat quality of the Yellow Springs Creek by systematically surveying aquatic invertebrates, monitoring water quality, and characterizing physical parameters of the stream. Collected data will provide information that indicates the health of the Glen Helen and will provide data that allows for comparison to other stream habitats in the nearby Little Miami river drainage basin (Figure 1). The upstream and downstream testing sites will act as controls for macroinvertebrate biodiversity and water quality.
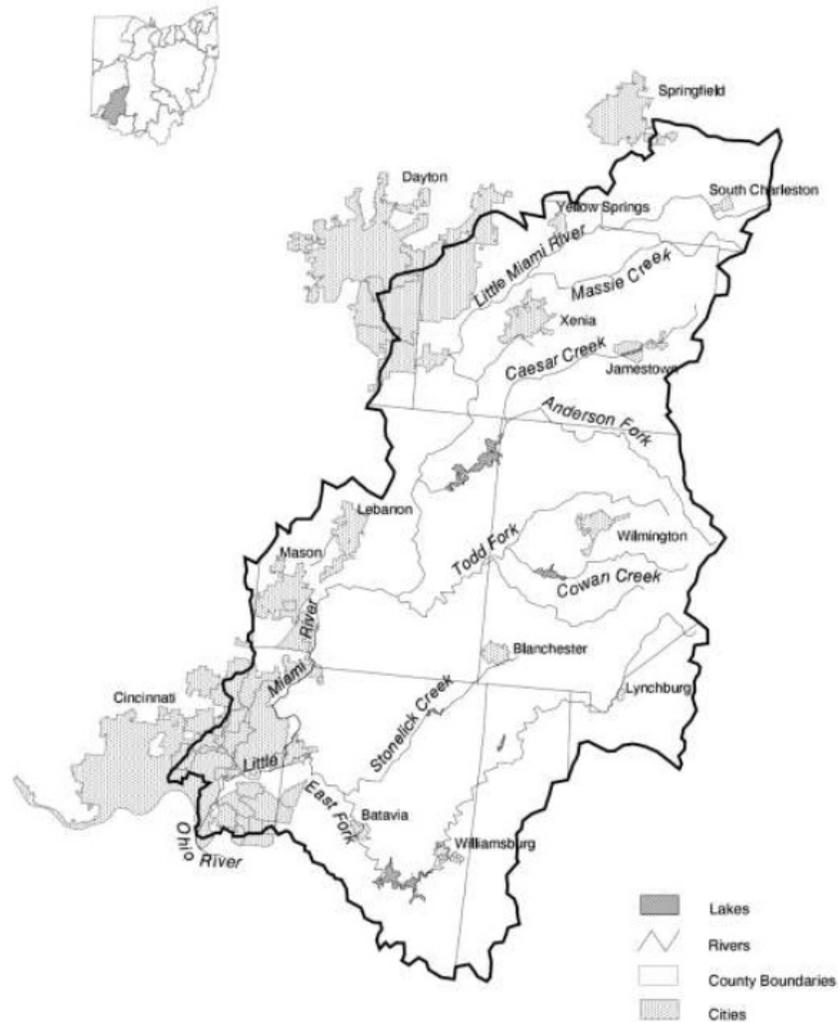
Figure 1. Map of the Little Miami river drainage basin (Ohio Environmental Protection Agency, 2015).

Before any collection or measuring, I will walk along publicly accessible river miles to find three sampling sites, with similar flow rates, depth, sunlight exposure, and other factors (ie. sinuosity). I will locate three separate testing sites with similar physical properties to maintain data collection consistency; 1) in the Glen Helen nature preserve, 2) upstream of Glen Helen, and 3) downstream of Glen Helen.The three sites will then be visited within one month to collected data, thus reducing variation due to changing weather. Additionally, data collection will be

collected opportunistically on days with similar weather (ie. all collection days are warm, sunny days).

Invertebrate biodiversity data will be collected by placing a kicknet downstream, with the opening facing upstream, and disrupting the substrate above stream with our feet (Wisconsin Department of Natural Resources, 2000; Civil and Environmental Consultants, Inc., 2007). Contents of the kicknet will then be emptied into a bucket (Wisconsin Department of Natural Resources, 2000; Civil and Environmental Consultants, Inc., 2007). The specimens will then be identified to taxonomic order and added to a running total. Specimens will be identified to taxonomic order because that is what most standardized metrics use for assigning an ICI score as seen in figure 2. All captured macroinvertebrates will be released back into the stream. Nine kicknet collections will be performed at each site three times in three different microhabitats including: 1) pool habitat with direct sun, 2) pool habitat under overhanging vegetation, and 3) in ripple habitats. Testing multiple microhabitats with different characteristics allows for collection of different taxonomic orders of macroinvertebrates that represent major areas of the habitat. Performing the collection multiple times better represents the abundance of species within each family found. After surveying our testing sites, I will analyze and quantify our aquatic invertebrate dating using the Invertebrate Community Index (ICI) (Ohio Environmental Protection Agency, 2015). I will give a score of 0 - 60 using the standardized metrics provided by the Ohio Environmental Protection Agency as shown in Figure 2.

| Metric | Scoring Criteria |
	0 2 4 6
1. Total Number of Taxa 2. Total Number of Mayfly Taxa 3. Total Number of Caddisfly Taxa 4. Total Number of Dipteran Taxa 5. Percent Mayflies 6. Percent Caddisflies 7. Percent Tribe Tanytarsini Midges 8. Percent Other Dipterans and Non-Insects 9. Percent Tolerant Organisms 10. Total Number of Qualitative Ephemeroptera, Plecoptera, And Trichoptera (EPT) Taxa	Scoring of each metric varies with site drainage area; see Ohio EPA (1989) or DeShon (1995) for scoring plots.

Figure 2. List of metrics used to assign an Invertebrate Community Index (ICI) score (Ohio Environmental

Protection Agency, 2015).

Water quality measurements will occur at the same time and location as our

macroinvertebrate survey. I will record data on temperature, pH, and dissolved oxygen content.

These measurements have been shown to be altered by agricultural runoff, such as pH shifts

(Orendt, 1999; Carew et al., 2007). Two separate YSI instruments (Xylem Inc., Yellow Springs,

Ohio) will be used for these measurements; one for temperature, and one all other measurements,

including pH and DO. I will take multiple water quality measurements at each site, to represent

each microhabitat (i.e. near rocks, under overhanging vegetation, in a muddy pool, etc).

At each testing location I will also assign a Qualitative Habitat Evaluation Index (QHEI)

score (Rankin, 1989; Ohio Environmental Protection Agency, 2006). This score will be

calculated using the Ohio Environmental Protection Agency's QHEI field assessment sheet that

factors in the physical properties of the stream including substrate type, channelization, depth,

and speed (Appendix 1). Factors such as substrate, sinuosity, and flow rate will be estimated at

the time of collection while factors such as stream width and depth will be measured at the time of the macroinvertebrate collection.

Significance of Study

Data used to first evaluate the health of the Yellow Springs creek was collected in 1998 and is no longer sufficient for current environmental assessments due to changes in environmental conditions, land use, and agricultural technologies (U.S. Department of Agriculture, 1999, 2012; Nehring et al., 2014; Pryor et al., 2014). Collecting current data on the Yellow Springs creek contributes to Glen Helen conservation practices by giving a more accurate representation of the stream quality health, especially in relation to surrounding areas. Additionally, collecting data on invertebrates and water quality within the Glen Helen that is recent can be used in classroom situations and can further advance the hands-on approach Antioch College strives to obtain. In the future Antioch college can continue doing invertebrate surveys as an integrated part of a class further increasing the educational value of the Glen Helen preserve. Furthermore, either the Glen Helen or Antioch College can survey for invertebrates during a different season and survey for fish to get more representative bioindicators for different potential pollutants. This is of interest to Antioch College due to the educational, research, recreational, and financial resources the Glen Helen provides. Collecting data on the Glen Helen gives us insight into the success of conservation efforts, and as we build a healthier ecosystem it can be further used as a promotional and education tool.

Table 2: Timeline from October 2017 – June 2018 indicating progress checkpoints on the proposed project.

	O	N	D	J	F	M	A	M	J
Data Collection	X	X							
Data Analysis		X	X	X					
Writing Paper				X	X	X	X		
Building Presentation							X	X	
Presenting									X

Table 3: Budget for proposed project. All costs calculated in USD.

Supplies	Cost	Notes
Kicknets	$0	Loan from Antioch
Buckets	$0	Loan from Antioch
Water Quality Measurement Kit	$0	Loan of Antioch
Identification Books	$0	Loan from colleagues
Gas for Car	$40	Traveling to/from sites

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