Ecological Assessment of the Fry's Run Watershed

Amanda deVillers
Andrew Mashintonio
Amy Parrish

Moravian College

Advisor: Dr. Frank Kuserk

Fall 2008

Abstract

The continual monitoring of an environment is important to maintain ecological integrity. In this study, physical, chemical, and biological assessments were conducted at three stream sites to evaluate the ecological health of the Fry’s Run Watershed. The physical habitat assessment consisted of the visual examination of several physical parameters of the stream to determine whether the site is able to sustain a suitable habitat. A number of water chemistry tests were performed to determine the water quality in the stream. The biological assessment included the sampling of macroinvertebrates and the calculating of biotic indices based on the species present. Site 3, located on a branch of the stream near a more mountainous area, had the highest overall quality. Site 2 had slightly lower overall quality due to the fact that it was located near agricultural land and was affected by fertilizer runoff. Site 1, which was located near the mouth of the stream system, had the lowest overall quality. Nevertheless, Site 1 was still of high quality, leading to the conclusion that the Fry’s Run Watershed is currently in good health.

Introduction

Pollution in streams from agriculture and industry is a growing concern. Active monitoring of watersheds is important to ensure healthy and ecologically stable environments. Three general areas of evaluation are recommended by the EPA to assess the health of streams: physical habitat assessment, chemical assessment of water quality, and biological assessment via macroinvertebrate sampling.

Ecological assessments, which have periodically been conducted at Fry’s Run over the past 30 years, have focused mainly on its quality as a habitat for fish and have recognized Fry’s Run as a high-quality coldwater fishery. Fry’s Run Watershed encompasses several areas of environmental significance, and the Fry’s Run stream runs over an aquifer which provides the main source of drinking water in the area. Changes in land use in the area and flood damage have been cited as areas of concern to the health of the stream (Brandes 2008). The purpose of this report is to analyze the current status of the Fry’s Run Watershed and to determine areas where improvements are needed to ensure the continued health of the watershed.

Physical Assessment

A physical habitat assessment enables researchers to determine the health of the stream using visual data. When monitoring a stream, habitat assessments are often completed several times a year to keep track of any seasonal changes or patterns that may occur. The EPA has created data sheets for use with physical habitat assessments (EPA 2008). These data sheets list a variety of parameters, including both visible evidence of water quality and physical characteristics, such as amount and type of substrate, dominant riparian vegetation, degree of channelization of the stream, and evidence of erosion. These parameters are designed to assess the health of the stream as a habitat for macroinvertebrates, fish and other organisms. By collecting data on each of these characteristics, one can determine the overall health of the stream. A list of ten parameters are included—Epifaunal Substrate/Available Cover, Pool Substrate Characterization, Pool Variability, Sediment Deposition, Channel Flow Status, Channel Alteration, Channel Sinuosity, Bank Stability, Bank Vegetative Protection, and Riparian Vegetative Zone Width. These are used to generate a numerical score for the habitat in the portion of the stream being studied. The first seven are ranked on scale of 0-20. A "Poor" ranking is between 0-5, "Marginal" is 6-10, "Suboptimal" is 11-15, and "Optimal" is 16-20. The last three parameters are ranked on a 0-10 scale, with each bank of the stream considered separately, resulting in a total score out of 20. A stream with a high score on this portion of the assessment likely provides a suitable habitat for a wide range of organisms, whereas a low score indicates a higher degree of human interference and a lower quality environment (EPA 2008).

Chemical Assessment

Water chemistry is extremely important to the health of aquatic environments. The way in which chemicals interact in a stream determines how well suited the stream is for certain organisms. The chemical properties of streams are influenced by surrounding land use, geology, and numerous other factors (Perry and Vanderklein 1996). In addition, there are several chemical constituents which play critical roles in the health of freshwater streams. Among these are the elements phosphorous, nitrogen, and sulfur. The interactions of these constituents, as well as numerous others, determine the quality of the stream. Acid-base reactions and oxidation-reduction reactions are the two major types of chemical interactions in freshwater streams (Baird and Cann 2005). The following sections describe the chemical components examined in this study.

Temperature

Many organisms, both vertebrates and invertebrates, are highly sensitive to temperature changes. They can only survive within a certain range, making temperature a crucial factor of stream quality (EPA 2008). Organisms will attempt to seek out an ideal temperature within their environment. If this is prevented or such a temperature is not available, the organism often dies. In some cases, especially with fish, certain temperatures are necessary for reproduction and other life processes. Temperature changes can also affect dissolved oxygen levels, photosynthetic and metabolic rates, and sensitivity to toxins. These changes can be caused by weather, removal or addition of shade, storm drainage, and pollution. An increase or decrease in temperature can completely change the types of plants and animals living in and around the stream (EPA 2008). Streams are classified as either warmwater or coldwater based on long-term temperature patterns. Seasonal temperature fluctuations are natural; however, a warmwater stream should remain below 32ºC, and a coldwater stream should not exceed 20ºC (Wilkes University 2008). Furthermore, any change greater than 1° or 2°C in less than 24 hours can result in stress or shock to the stream ecosystem and inhabitants (Campbell and Wildberger 2001).

Hardness

Hardness is a measurement of the amount of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water. Water is considered hard if the ion concentration exceeds 150 mg/L (Baird and Cann 2005). Ca^{2+} and Mg^{2+} ions enter streams mainly through the weathering of rocks, so hardness depends greatly on the geology of the stream region (Murphy 2007). For example, limestone is composed of calcium carbonate ($CaCO_3$), and over time $CaCO_3$ will dissolve into water as Ca^{2+} and CO_3^{2-} ions (Baird and Cann 2005). Since hardness is dependent on the geology of a region, there are no standard concentrations (Murphy 2007). Other metals, such as Fe^{2+} and Mn^{2+}, are sometimes included in hardness measures. Presence of metals like Fe^{2+} can be an indication of human impact on a stream through pollution (Kreager 2004).

Hardness levels have varying effects on stream life. Calcium and magnesium are both important nutrients for organisms, making their presence essential to a stream (Kreager 2004). A positive correlation has also been suggested between species richness and hardness (Allan 1995). However, it has been shown that if hardness levels are too high, it can be detrimental to fish health because metals can bind to the gills, causing death (Meyer *et al.* 1999).

pH and Alkalinity

pH is a measure of the acidity of water. More accurately, it is a measure of the potential activity of the hydrogen atoms in the sample. pH is measured on a scale from 0 to 14; solutions below 7 are acidic, above 7 are basic, and at 7 are considered neutral. Streams typically have a slightly basic pH value ranging from 7 to 8 (Vernier 2007). Most organisms have optimal pH ranges in which they live that fall between 6 and 8 (Campbell and Wildberger 2001). Even slight changes in the normal pH can have considerable effects on stream life.

Several factors can affect pH levels, some more significantly than others. The bedrock and composition of the soil through which the water flows can have a profound effect on the pH level (Wilkes University 2008). Limestone is a type of rock that neutralizes acids, whereas granite has little or no effect on pH. Algal blooms and other organic materials can cause increases in the level of pH. Additionally, chemicals that are dumped into the water by industries or individuals can cause major pH changes. Acid rainfall lowers the pH of the stream (Vernier 2007).

pH is highly linked to alkalinity, the ability of water to resist changes in pH, otherwise known as its buffering capacity. Certain compounds, most notably carbonate-bicarbonate compounds, act as buffers, keeping the pH from becoming too acidic (Wilkes University 2008). A solution with a small buffering capacity, or low alkalinity, will experience an abrupt change in pH after the addition of an acid, whereas a solution with a higher alkalinity will be able to resist that change. Carbonate compounds are able to buffer water by absorbing extra H^+ ions that have been added, thus preventing the pH from dropping.

Alkalinity in streams is determined by the amount of bicarbonate compounds present. Streams with good buffering capacity have values that range between 20 and 200 ppm (Campbell and Wildberger 2001). Values less than 10 ppm indicate a poorly buffered stream that is susceptible to abrupt changes in pH.

The level of alkalinity in a stream also depends on the rocks and soils over which it flows. Rocks containing carbonate, bicarbonate, hydroxide compounds, borates, silicates, and phosphates all contribute to alkalinity. Streams that contain mostly granite and sandstone usually have low alkalinity. Limestone is also a good source of carbonates, so alkalinity is often linked with hardness. Since hardness in a stream is mainly caused by dissolving $CaCO_3$ as the concentration of Ca^{2+} increases, CO_3^{2-} increases proportionally, contributing to alkalinity. The metal carbonates in hard water contribute to an ability to resist changes in pH, but soft water often lacks these carbonates, resulting in a lower alkalinity level (Oram 2008).

Dissolved Oxygen and BOD

Dissolved oxygen (DO) concentration is one of the most important parameters of a life-sustaining stream. It functions as the main oxidizing agent in the stream as well as provides aquatic life with necessary oxygen. DO concentration refers to the amount of oxygen gas (O_2) dissolved in a liquid and is measured in milligrams per liter (mg/l) or as a percentage of saturation. The median concentration of DO in the United States is 10 mg/L (Baird and Cann 2005).

Several factors influence DO concentrations in natural waters. Oxygen enters water by diffusion of atmospheric oxygen. Air is 21% oxygen ($pO_2=0.21$), making the expected natural concentration of DO in water 8.7 mg/L. Oxygen solubility increases with decreasing temperature. Thus, colder waters can hold more DO than 8.7 mg/L (Baird and Cann 2005). DO is consumed by aquatic organisms and oxidation of molecular components in the stream, so oxygen must be replenished in order to maintain DO levels. This replenishment occurs in flowing streams via riffles where the water is mixed with air by collisions with substrate. In stagnant water, this mixing does not occur, and waters tend to become oxygen depleted. In order to sustain aerobic life, DO concentration must be greater than 5 mg/L. Oxygen can also be replenished through photosynthesis by algae or aquatic plants which utilize CO_2 from the atmosphere and release oxygen. As a result of these factors, DO levels fluctuate throughout the day as well as seasonally (EPA 2008).

DO concentrations determine in part the form in which molecules appear. In a stream with a healthy DO concentration, compounds will be present in their oxidized forms, and organic substrates will be readily oxidized. If DO concentrations are low, the water will be reducing in nature, and compounds like methane (CH_4) would be produced rather than the oxidized form, carbon dioxide (CO_2) (Baird and Cann 2005).

Aquatic life depends greatly on dissolved oxygen. A stream with healthy DO concentrations can sustain a plethora of life, including diverse fish and invertebrate species, plants and algae, and microorganisms. In low DO concentrations, aquatic life is limited to anaerobic microorganisms and certain algae (EPA 2008).

Aside from the actual concentration of oxygen in the water, another measure of water quality is the Biological Oxygen Demand (BOD). BOD is a measure of the capacity to consume oxygen by biological and organic matter in the water. BOD is measured by determining the change in DO concentration over a five day period in which the water sample is stored in a dark environment. BOD levels are mainly a result of oxidation of organic matter, such as dead plants or animal wastes. These oxidation reactions are catalyzed by microorganisms. In unpolluted waters, the median BOD is 0.7 mg/L, whereas severely polluted waters, such as those containing sewage, typically have BOD values in the hundreds (Baird and Cann 2005).

BOD levels are important to the functioning of aquatic ecosystems for the same reasons as DO concentrations. In a stream with a high BOD, oxygen concentrations can quickly become depleted if oxygen is not replenished. Aquatic organisms will have an inadequate oxygen supply and will become stressed and die off. Sources of pollution which raise BOD include dead plants and animals, urban storm-water runoff, waste-treatment plants, poor septic systems, paper mills (pulp), and animal manure and feedlots (EPA 2008).

Oxidation Reduction Potential (ORP)

Oxidation Reduction Potential (ORP) refers to the tendency of a system to either gain or lose electrons in chemical reactions. An atom is reduced when it gains electrons and oxidized when it loses electrons. ORP is critical in natural systems because it determines the forms of molecules that are present (Baird and Cann 2005).

ORP is indirectly measured as the ability of a system to conduct electricity in millivolts (mV). High ORP values indicate that a system promotes oxidation, while low ORP values indicate that a system promotes reduction. ORP values between 300 and 340 mV are generally considered ideal for freshwater ecosystems. ORP values above 400 mV can be fatal for living organisms (Fenner 2008).

Many oxidation-reduction reactions determine the molecular composition of a stream and its ability to sustain life. Decomposition of organic matter depends on oxidation catalyzed by microorganisms. Concentrations of metals such as iron (Fe) are also affected by ORP. Fe^{3+} is insoluble in water and collects in sediments in many freshwater systems. The reduced form, Fe^{2+}, is water soluble and thus present in reducing systems. Similarly, ORP helps to determine the form nitrogen takes in aquatic systems. Nitrification (conversion of ammonia and ammonium ion to nitrite and nitrate) is a process driven by oxidation, and denitrification (conversion of nitrite and nitrate to molecular nitrogen) is driven by reduction (Baird and Cann 2005).

ORP is generally affected by two factors: DO concentration and pH. As discussed previously, DO is the major oxidizing agent in freshwater streams. With higher concentrations of DO, the stream will be oxidizing and have a positive ORP. Similarly, at higher pH levels, systems will tend more toward oxidation, and at lower pH levels, systems will tend toward reduction (Baird and Cann 2005).

Salinity

Salinity is the measure of all salts dissolved in water, expressed in parts per thousand (ppt). Different species of plants and animals thrive in different salt concentrations. Water conductivity is directly related to salinity—the higher the salt concentration in water, the better the water conducts electricity. There is little or no salinity in most inland water systems.

Total Dissolved Solids

The amount of total dissolved solids (TDS) refers to the amount of material totally dissolved in water, or that which can pass through a filter. Examples of dissolved solids include sodium, calcium, magnesium, bicarbonate, sulfate, and chloride. Solids, such as silt, bottom sediment, and decaying plant matter, can also be suspended in streams. TDS is a good gauge of the quality of drinking water; levels that are too high will result in hard water with a distasteful mineral flavor. The EPA has implemented standards for drinking water at 500 mg/L (Vernier 2007).

Some amount of dissolved solids is necessary to support aquatic life in streams. Because the density of water controls osmotic flow through cellular membranes, changes in TDS are typically harmful to life. These changes can be measured through the use of a conductivity probe. Increases are typically the result of runoff from surrounding areas. Fertilizers from lawns and agricultural areas contribute a wide variety of different dissolved solids, whereas urban areas often add solids, such as rock salt from streets (Murphy 2007). There are many other sources of TDS. Rocks and soils that contain calcium and carbonate will release these ions when water flows over them. Wastewater that is released into streams is usually only treated for suspended solids, allowing many dissolved solids, such as nitrogen and phosphorus, to be added to streams. Acidic rainfall contributes nitrates and sulfates, and decaying plants and animals add organic molecules. TDS values are normally between 50 and 250 mg/L, though they can be as high as 500 mg/L if enough ions are added (Vernier 2007).

Nitrates, Nitrites, and Ammonia

Nitrogen is a common pollutant of freshwater systems. It is typically found in three different forms: nitrate, nitrite, and ammonia. Nitrates are a less toxic form of nitrogen, but bacterial activity often converts nitrates into nitrites. Nitrites are extremely detrimental to freshwater ecosystems, even at low levels. Ammonia is another potentially deadly nitrogen-based compound that is frequently found in streams. These nitrogenous compounds are commonly found in water that has come into contact with fertilizers, septic systems, manure, or naturally occurring nitrogen deposits. These three compounds have all been found to affect eutrophication, dissolved oxygen levels, and temperature, often causing significant changes in the amounts and types of plant and animal life in the watershed. In vertebrates, including humans, nitrites can severely compromise the ability of hemoglobin to bind and transport oxygen. Natural levels of these compounds should be less than 1 mg/L, as nitrogen is necessary for plant life; however, when the levels escalate, hypoxia and toxicity often result.

The EPA has set limits for nitrates and nitrites in drinking water because they are harmful to humans. A healthy freshwater ecosystem should have levels similar to the EPA standards. For drinking water to be safe, nitrate levels should be less than 10 ppm, nitrites should not exceed 1 ppm, and the sum of both nitrates and nitrites should also be less than 10 ppm.

Phosphate

Phosphates also appear in different forms in natural waters, both organic and inorganic. When assessing water quality, scientists test for meta- and orthophosphates as well as the total phosphate levels. This study will focus only on orthophosphate (PO_4^{3-}), as this is the only form available to living organisms (Kreager 2004).

Living organisms depend on orthophosphate to complete their metabolic functions, making it an essential compound to their daily lives. In most natural systems, phosphate is a growth limiting factor, meaning that it is present in very small amounts and restricts the speed of growth in a community. Excess phosphate is introduced to streams through agricultural runoff and sewage. If phosphate levels are high due to these types of pollution, algae can thrive, and water systems experience bursts in algae populations. Eventually, the algal population dies, and decomposition of this matter causes the depletion of DO in the system (Baird and Cann 2005).

Hydrogen Sulfide

Hydrogen sulfide is a component of natural gas that is extremely dangerous when present in high amounts. Breathing this gas can be lethal; therefore, it is an important parameter for measuring water quality. The maximum value of hydrogen sulfide allowed by EPA in streams is 14 ppm, or 20 mg/m^3 (Varga *et al.* 2007). Most streams have hydrogen sulfide values far below the limit; therefore, it is rarely tested for.

Biological Assessment

Benthic macroinvertebrates are useful bioindicators for the health of the streams in which they live. Some groups of macroinvertebrates are only found in healthy streams. Others can be found in all streams but in greater abundance in polluted streams. Three orders of macroinvertebrates, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), are associated with healthy streams, whereas Diptera (true flies) are found in more polluted waters. The relative abundance of the tolerant and intolerant species is an indicator of the health of the stream. This is empirically determined through the use of a biotic index. In order to assess the presence of these indicator species, macroinvertebrates are sampled and identified to the family or genus level.

Materials & Methods

Three locations within the Fry's Run Watershed were chosen as study sites. Site 1 is located at Royal Manor Road at the end of the water system, just before it enters the Delaware River. This site is bordered by a road and a park. Site 2, at Durham Road, is located several miles upstream with a cornfield bordering one side. Site 3, at Morgan Hill Road, is of a similar distance from the Delaware and passes near residential areas in more mountainous area. The same sampling methods were used at each site.

Using the guidelines published by the EPA, a physical habitat assessment was performed at each site. Detailed information was recorded regarding many aspects of the stream and surrounding area at each site. A stretch of the stream of approximately 50-75 meters was chosen for assessment, and identification information was recorded, assuring that the assessment remained as accurate as possible. Current and recent weather conditions were recorded. The stream subsystem, type, and origin were determined, and any non-point sources of pollution, evidence of erosion, and the type(s) of surrounding land use were noted. An analysis of the riparian vegetation, including types of plants and the dominant species, completed the portion of the assessment dealing with surrounding terrestrial features. Several instream features were also analyzed, including canopy cover, any visible high water mark, any evidence of channelization, and proportion of riffles, runs, and pools. Any aquatic vegetation was noted, again listing the dominant species. Any odor, visible oil, and turbidity were recorded, as were sediment deposits and inorganic and organic substrate components. The final portion of the habitat assessment involved a list of 10 parameters, each of which were ranked as Optimal, Suboptimal, Marginal, or Poor, and given a score. The individual scores for each portion were added to give the overall score for the stream at that particular site.

Water quality was tested at each of the three stream sites based on the following chemical parameters: pH, salinity, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), nitrate and nitrite concentration, concentration of phosphates, total hardness, alkalinity, ammonia concentration, and biological oxygen demand (BOD).

A YSI multi-parameter water quality probe was used to measure the temperature, pH, salinity, conductivity, DO, and ORP at each site. These readings were taken on three separate days throughout September or early October during the macroinvertebrate collection. The probe was set in the stream and left undisturbed for at least 30 minutes so that the sensors could equilibrate.

The remaining parameters, including nitrate, nitrite, phosphate, and ammonia concentrations as well as total hardness and alkalinity, were analyzed from water samples taken at each site. BOD bottles were used to collect water samples in late September. Samples at all three sites were collected on the same day. Samples were kept on ice or in the refrigerator until the analysis was done. The Total Hardness, Ammonia, Total Phosphate, Nitrate-Nitrite, and Alkalinity test kits by HACH were used to make the analysis and all of the protocols were followed according to the kits.

The biological oxygen demand from each stream site was determined in early October. Two BOD bottles (one black and opaque, one colorless and transparent) were filled with water at each of the three sites. On site, 1 mL of manganous sulfate solution (48 g $MnSO_4 \cdot 4H_2O$ or 40 g $MnSO_4 \cdot 2H_2O$ in 100 ml H_2O) was added to the clear bottles followed by 1 mL of alkali-iodide-azide reagent (50 g NaOH + 13.5 g NaI in 100 mL H_2O). This solution was mixed by inversion in order to fix O_2 in the sample. All bottles were kept on ice while in the field. Upon returning to the lab, the clear bottles containing the fixed samples were analyzed. One ml of concentrated sulfuric acid was added to each fixed sample, and the bottles were shaken to dissolve the iodide precipitate. After adding a few drops of starch, 200 mL of this solution was titrated with sodium thiosulfate (6.205 g $Na_2S_2O_3 \cdot 5H_2O$ + 0.4 g NaOH in 1 L H_2O) until the solution became clear. The amount of DO in the sample (mg/L) is equal to the amount in milliliters of sodium thiosulfate used. The black BOD bottles were incubated at 20 ºC for five days, after which the same procedure was followed to determine the DO. The BOD for each stream site was determined by subtracting the DO reading from Day 5 from the DO reading from Day 1. (Clessceri et al. 1998).

We sampled macroinvertebrate species at each of the three stream sites. Each total stream sample consisted of four separate samples in various locations along the sample length of the stream. These four locations were chosen arbitrarily. Each sampling area was ½ x ½ meters. We used 500 µm mesh nets that ended in a jar to collect the specimens. The sampling net was situated on the downstream edge of the quadrat. First, large rocks in the sampling area were rinsed and then discarded. Next, one person kicked up the sediments within the quadrat towards the net for about one minute. Finally, the contents of the jar were transferred to a collection bucket. All four samples at a given site were combined into the collection bucket.

The samples were preserved in 70% ethanol in the lab. Leaves and twigs were separated from the sample. Next, the sample was spread into a 24-square grid and four squares were randomly sub-sampled. All of the invertebrates were collected from each square. If the total number of organisms was less than 200, we continued collecting from random squares until we reached 200. The macroinvertebrates were then sorted by appearance under a dissecting scope and identified to the family or genus level using an identification guide (Meritt *et al.* 2008).

Once identified, two diversity indices, the Family Biotic Index (FBI) and the Shannon Index, were calculated to assess the health of the stream. The FBI, adapted from the Hilsenhoff Index, ranks each family of macroinvertebrates on a tolerance scale. Low values represent intolerant taxa, whereas higher values are assigned to more tolerant taxa. If a macroinvertebrate is intolerant, it is usually only found in streams that have low levels of pollution; therefore, the index uses the abundance of each family present to determine how healthy the stream is based on a ranking scale. The Shannon Index, however, does not distinguish between tolerant or intolerant species; it is merely a measurement of how many different species are present in a stream and how evenly distributed those species are.

Results

Table 1. Physical Habitat Assessment Scores

Habitat Parameter		***Site 1***	***Site 2***	***Site 3***
Epifaunal Substrate/Available Cover		15	13	18
Pool Substrate Characterization		9	19	13
Pool Variability		8	18	13
Sediment Deposition		13	14	20
Channel Flow Status		19	19	19
Channel Alteration		19	15	20
Channel Sinuosity		15	12	11
Bank Stability	**Left Bank**	6	9	9
	Right Bank	9	9	9
Vegetative Protection	**Left Bank**	7	10	10
	Right Bank	9	10	10
Riparian Vegetative Zone Width	**Left Bank**	6	4	3
	Right Bank	8	4	2
Total Score		143	156	157
Average Score		14.3	15.6	15.7

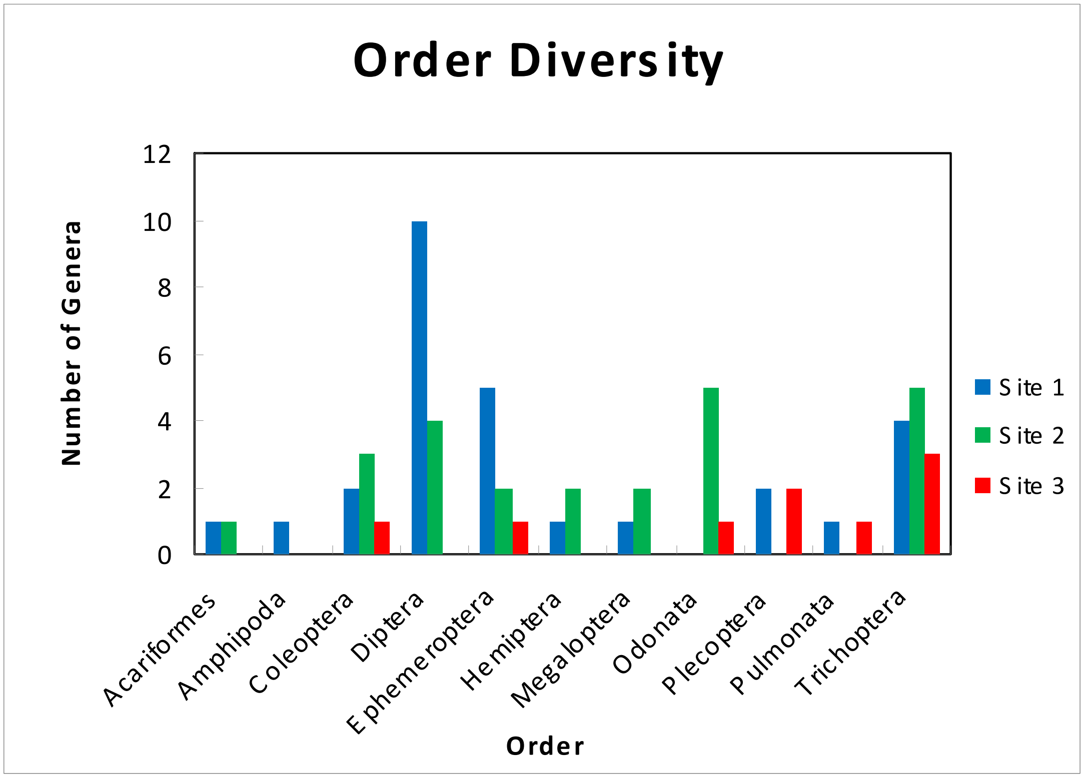
The results of the habitat assessment show that all three stream sites were at the high end of the suboptimal range (Table 1). All had an average score within 1.5 points of each other; however, scores for individual parameters varied between sites. For example, the riparian vegetation was severely lacking at Sites 2 and 3 while Site 1 had marginal values for pool substrate characterization and pool variability (Table 1). All three stream sites were in the upper range of the channel flow status, which means that the water completely reached both banks. Due to a bridge at Site 2, the channel alteration was ranked lower than those of the other two sites.

Table 2. Comparison of Water Chemistry Data to Past Studies

Site	***Date***	***T (°C)***	***pH***	***DO* (mg/L)**	***DO* (% sat.)**	***BOD* (mg/L)**	***o-phosphate* (mg/L)**	***Nitrates* (mg/L)**	***Nitrites* (mg/L)**	***Ammonia* (mg/L)**
Site 1	12/16/97	5.8	6.6	9.7	77.5			1.65	0.01	0.05
Site 1	10/28/07	13.5	7.5						0.03	0.0024
Site 1	**9/24/08**	**16.4**	**8.41**	**9.6**	**97.8**	**0.1**	**0**	**1**	**0**	**0.2**
Site 2	12/16/97	7.2	8	10.9	90.2			2.46	<0.01	0.02
Site 2	10/26/07	14.4	7.5						0	0.0024
Site 2	**9/24/08**	**18.1**	**8.6**	**9**	**95.1**	**0.3**	**0.16**	**0**	**0**	**0.3**
Site 3	10/28/07	13.5	7.5						0	0.0024
Site 3	**9/24/08**	**16.9**	**8.8**	**9.9**	**102.5**	**0.1**	**0**	**0**	**0**	**0.3**
Standards		-	7-9	>5	80-124	0.7	<0.1	<1-2	<0.1	<0.5

The results of the water chemistry tests are compared with data taken in previous years at all three stream sites (Table 2). The pH remained in the acceptable range and was slightly basic, as is expected in a limestone-dominated region. DO and BOD data were excellent for all three sites, indicating an oxygen-rich environment with low pollution. Orthophosphate concentrations were negligible at Sites 1 and 3 but were noticeably higher at Site 2. Nitrate and nitrite levels were overall very good and appear to have decreased from 1997 at Sites 1 and 2. Ammonia concentrations have increased since 1997 at all three sites, but are still below the critical value of 0.5 mg/L. Hardness and alkalinity data was inconclusive due to difficulties with the test kits and therefore were not included in the results. Additional water chemistry results can be found in Appendix B.

Figure 1. Order Diversity between Stream Sites



A considerable difference in the diversity between the three stream sites has been observed. Of the three healthy indicator groups, only Trichoptera and Ephemeroptera were found in all three stream sites (Figure 1). Additionally, there was a substantial amount of diversity of Diptera at Site 1, whereas the order was completely absent at Site 3. There is a shift in the dominant order at each site, varying from the pollution sensitive Trichoptera at Site 3 to the hardier Diptera at Site 1.

Figure 2. Percentage of Orders at Each Site

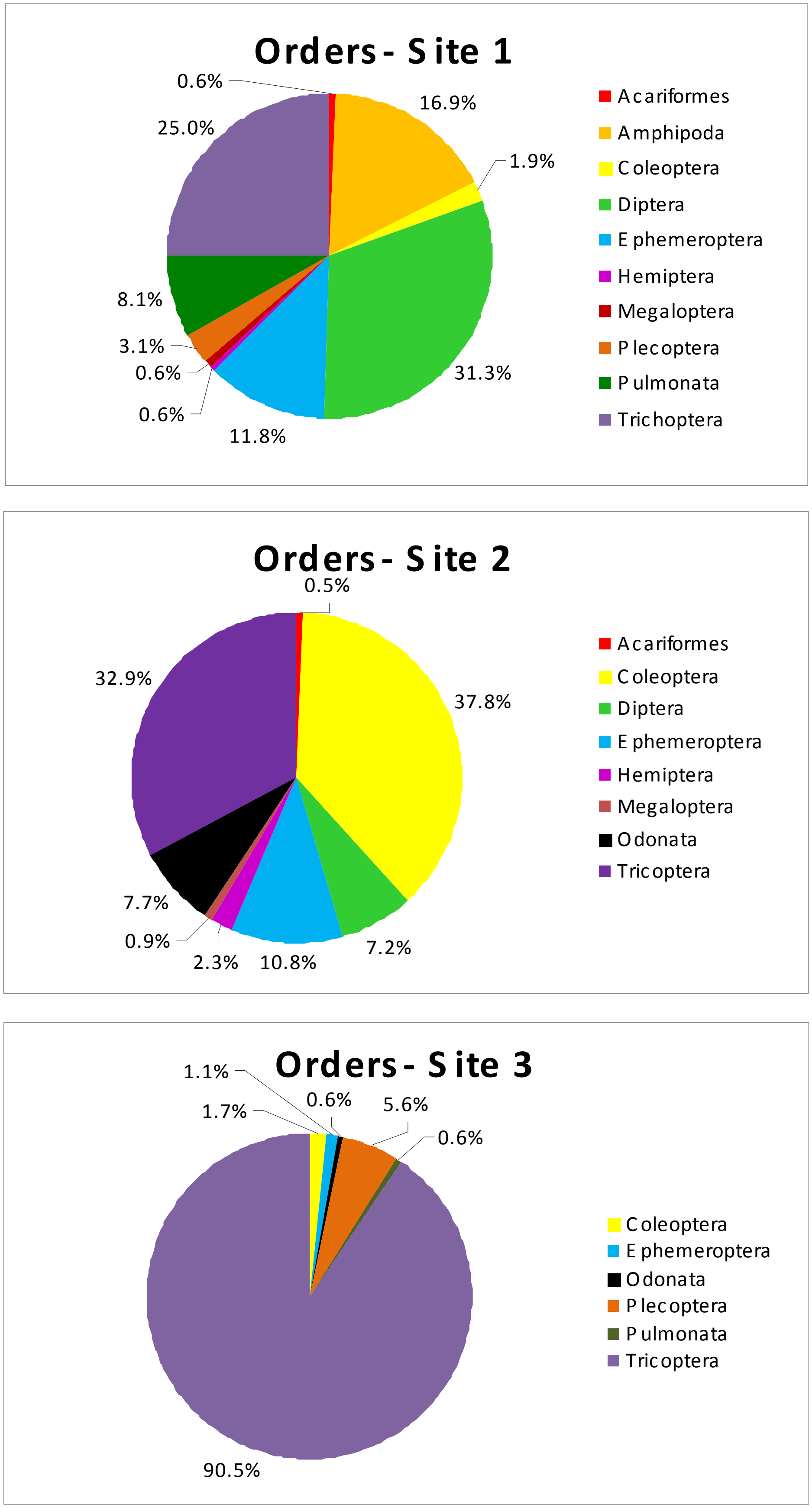


Table 3. Comparison of Macroinvertebrate Data among Stream Sites

Composition Measures:	***Site 1***	***Site 2***	***Site 3***
Total Number	162	222	180
Total Taxa	30	23	9
Dominant Taxa	*Hydropsychidae*	*Elmidae*	*Chimarra*
% Dominant Taxa	21.6	30.2	57.2
Ratio EPT/Diptera	1.3	6.1	(---)
% EPT	39.5	43.7	97.2
% Ephemeroptera	11.7	10.8	1.1
% Plecoptera	3.1	0.0	5.6
% Trichoptera	24.7	32.9	90.6
% Diptera	30.9	7.2	0.0
Shannon Diversity Index (H')	2.69	2.19	1.08
H' Max	3.4	3.14	2.2
Evenness (J)	0.79	0.70	0.49
FBI Value	4.81	3.85	3.27
FBI Rank	Good	Very Good	Excellent
# Very Intolerant Taxa (FBI <2)	6	4	3
% Individuals in Tolerant Taxa (FBI ≥ 5)	48.77	11.71	0.55

The proportion of EPT is highest at Site 3 (Table 3), due mostly to two families of Trichoptera, and lowest at Site 1. EPT percentages represent the relative abundance of the three intolerant indicator species. The evenness at Site 3, however, is extremely low due to the overabundance of Trichoptera species (Table 3). While evenness can be a good indicator of balance among species, it is not necessarily a sign of stream health. This is supported by the fact that Site 1, which has a lower EPT value, has a higher evenness score. Shannon Diversity Index values varied among sites (Table 3). Diversity is typically used as a measurement of stream health; however, in this case, as Shannon Diversity increased, the proportion of sensitive species decreased. Also, all three sites have a FBI value of less than 5, resulting in a ranking of "Good" or higher.

Discussion

Taking into account all three types of assessment, Site 3 showed the highest overall quality. This site received the highest score on the physical habitat assessment, had the greatest EPT percentage, and the best FBI ranking. There were also no areas of concern for water quality. Although the Shannon Index was low, this does not indicate a poor stream because it was dominated by an intolerant species. Additionally, no Diptera were found, providing further evidence that the stream is healthy. Since Site 3 is located within a tributary flowing through a more mountainous area, it is expected that the stream quality would be higher.

The tributary in which Site 2 is located originates in an area which is dominated by agricultural land. This would lead to the prediction that Site 2 would have a lower stream quality than Site 3. The results support this relationship. Although the physical habitat assessment overall score was nearly identical to Site 3, the water quality was lower. Orthophosphate levels were elevated compared to the other sites, the DO concentration was lowest, and the BOD value was highest, all of which are likely due to fertilizer runoff from the neighboring cornfield. All of the values for the biotic indices were between those of the other two sites. This is further evidence that Site 2 is of poorer quality than Site 3.

Site 1 appears to be the least healthy of the stream sites. This site has the lowest average score for physical habitat assessment, the lowest percentage of EPT, and the lowest FBI ranking. Lower health quality is to be expected here, since Site 1 is near the mouth of stream and is the result of many sources throughout the watershed, allowing for more opportunities for the accumulation of pollutants. Despite this, the physical habitat assessment ranking was still in the “Suboptimal” range, and the FBI ranking was “Good.” Also, this site had the highest Shannon Index value. This is likely due to that fact that it is the result of the convergence of the many sources for this watershed, resulting in a mixture of populations from a variety of origins. Furthermore, the site has good water quality based on the water chemistry tests. This is a positive sign for the health of the watershed, since sites upstream in the watershed will likely have less pollution than at the mouth.

Although the results of this study indicate that the Fry’s Run Watershed is currently in good shape, frequent monitoring is important to ensure the continued health of the watershed. Possible areas of future concern are runoff from agricultural fields around Site 2 and the increasing rate of residential development near Site 3. Each of the types of assessments should be conducted at least twice a year to get an accurate picture to account for seasonal variation. With a concerted effort by the watershed association, sustained health of the stream is an achievable goal.

Literature Cited

Allan D. 1995. Stream Ecology: Structure and Function of Running Waters. Springer. p. 40

Baird C, Cann M. 2004. The Chemistry of Natural Waters. In: Environmental Chemistry. 3rd ed. New York: W.H. Freeman and Company 2004. p. 425-462.

Brandes K. 2008. Fry's Run Coldwater Heritage Plan. Fry's Run Watershed Association.

Clessceri L, Greenberg A, Eaton A. 1998. Oxygen (Dissolved): Iodometric Methods. In: Standard Methods for the Examination of Water and Wastewater. 20th ed. p. 4-129 – 4-130.

Fenner B. Redox; Reduction-Oxidation Potential, ORP [Internet]. CRP Aquatic, Inc.; [cited 2008 Oct 10]. Available from: http://www.wetwebmedia.com/redox.htm

Kreager C: Water Quality Assessment [Internet]. Wheeling (WV): Center of Educational Technology; [updated 2004 Nov 7; cited 2008 Oct 15]. Available from: http://www.cotf.edu/ete/modules/waterq3/WQassess1.html

Meyer J, Santore R, Bobbitt J, Debrey L, Boese C, Paquin P, Allen H, Bergman H, Ditoro D. 1999. Binding of Nickel and Copper to Fish Gills Predicts Toxicity When Water Hardness Varies, But Free-Ion Activity Does Not. Environmental Science Technology. 33: 913-916.

Monitoring and Assessing Water Quality [Internet]. Washington (DC): U.S. Environmental Protection Agency; [updated 2008 Oct 8; cited 2008 Oct 3]. Available from: http://www.epa.gov/owow/monitoring

Murphy S: BASIN: general information on solids [Internet]. Boulder (CO): USGS Water Quality Monitoring; [updated 2007 Apr 23; cited 2008 Sep 5]. Available from: http://bcn.boulder.co.us/basin/data/BACT/info/TDS.html

Oram B: General water quality [Internet]. Wilkes-Barre (PA): University Center for Environmental Quality; [cited 2008 Aug 29]. Available from: http://www.water-research.net/Inorganic_Testing.htm

Perry J, Vanderklein E. 1996. Rivers and Streams: One-way Flow Systems. In: Water Quality: Management of a Natural Resource. Blackwell. p. 159-180

pH [Internet]. Beaverton (OR): Vernier Software & Technology; c2007 [cited 2008 Sep 6]. Available from: http://www2.vernier.com/sample_labs/WQV-02-COMP-ph.pdf

Total dissolved solids [Internet]. Beaverton (OR): Vernier Software & Technology; c2007 [cited 2008 Sep 6]. Available from http://www.vernier.com/cmat/wqv.html

Varga A, Mohacsi A, Puskas A, Bozoki Z, Szabo G. 2006. Photoacoustic system for online process monitoring of hyhdrogen sulfide (H_2S) concentration in natural gas streams. Appl Phys B-Lasers O. 85 (2): 315-321.

Wellcare information for you about Nitrate and Nitrite & Groundwater [Internet]. Washington (DC): Water Systems Council; [updated 2007 Jan; cited 2008 Oct 12]. Available from: www.watersystemscouncil.org/VAiWebDocs/WSCDocs/9066584Nitrate_and_Nitrite_FINAL.pdf