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The Differences In Benthic Macroinvertebrate Communities When A Comparison Is Made Between Multiple Reaches With Special Attention To Man-Made Structures

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Abstract

Macroinvertebrates as indicator organisms in determining water quality is a cheap and rather easy method for anyone to help research in this area become more accurate and efficient. Amassing different results from research that is done using different tools, methods, or looking at different aspects of the same problem is key to narrowing down the most effective way to consistently assess water quality while still being cost effective. This experiment looked at the quality of Lily Cache Creek water in Illinois and made comparisons to adjacent reaches of the same creek both upstream and downstream. Man-made structures near-by both adjacent sites were observed for the possible effects of those structures on water quality as well. Guidelines set by the Illinois RiverWatch were adhered to during this research involving training, sampling methods, and sorting/ identification. The results showed that there was little difference in the biotic index and Shannon diversity index between an established and adjacent site. However, there was a significant difference between EPT/ non-EPT and pollution intolerant/ tolerant organisms found at these sites, as well as a noticeable difference in taxa distribution. In conclusion, the results of this experiment showed that when waters from two different reaches (established and adjacent) of the same stream no more than 300 feet (61.16 m) apart was compared the overall quality (MBI) of the stream did not change From Fair. The most noticeable differences between the sites were the comparison of EPT to non-EPT, pollution intolerant to pollution tolerant organisms, and taxa distribution.

1. Introduction

The primary objective of biological surveys is to quantify the difference between naturally occurring stress and man-made stress that may be placed on a body of water[1]. Sampling macroinvertebrates provides a means to indirectly assess the quality of stream water. By definition benthic macroinvertebrates are all invertebrate organisms that live on or are closely associated with the bottom of a body of water and can be seen without the aid of a microscope[2]. These organisms are used for sampling because they are relatively easy to collect and identify. They spend most of their lives in one area of a stream and do not naturally move to other distant areas of the stream; if there is a shift in a macroinvertebrate community the change usually signifies that there is a problem due to some kind of stress in the stream. Furthermore, these organisms represent the quality of the stream over time instead of the quality of the water at any single point of time. Not only does a Macroinvertebrate community represent a continuous indication of water quality, but it also reflects the stability and diversity of the larger aquatic food web they are a part of.[2] This same food web, and its various interconnectivity of species also leads to humans, as a result, if pollution is harmful to a species beneath humans in our food web we will surely see that same pollution in our own bodies eventually as a result of bioaccumulation. Organisms that provide a continuous indication of their habitat quality are known as indicator organisms.

Indicator organisms are organisms that respond predictably to various environmental changes[2]. Macroinvertebrates act as indicator organisms in their habitat to indirectly measure the quality of the water in which they live[2]. The presence or absence of specific indicator organisms determines the water quality; this is because specific organisms are able to tolerate pollution differently. Some organisms can tolerate low quality water while others can only tolerate higher quality water. The biotic index used in this study was developed to detect organic pollution such as sewage[2]. Each taxon has a pollution tolerance index rating ranging from 0.0, which would indicate that species is intolerant to pollution; to 11.0 the species is tolerant to pollution. Organisms that are commonly abbreviated as (EPT) or the Mayfly (Order Ephemeroptera), Stonefly (Order Plecoptera), and Caddisfly (Order Trichoptera) order have low tolerance index rating values[3]. For example, the elusive Stonefly has an index rating of 1.5 so its presence is a good indication of clean water. To measure the level of a particular stress, a biological score system is used[1]. There are various indices used to detect specific pollutants at various levels of identification. The RiverWatch biological survey samples Macroinvertebrates for 37 different indicator taxa[2]. Taxa were identified at the level of order and occasionally family. Indexes Calculated in the biological survey include a Macroinvertebrate biotic index, number of organisms sampled, Taxa richness, and EPT Taxa richness[2]. This index Ranges in quality values from Excellent (≤ 4.35), Good (≥ 4.36 - ≤ 5.00), Fair (≥ 5.01 - ≤ 5.70), Poor (≥ 5.71 - ≤ 6.25), and Very Poor (≥ 6.26). When conducting a survey it is important to know when samples should be collected, but it is also important to be able to recognize different areas of a stream.

A stream may have a few different areas where samples may be collected. A rocky bottom reach is composed of riffles (turbulent water passing over stones), runs (stretches of quiet water with a moderate current), and pools[2]. Soft bottom reaches are composed of sand, soft mud, or a mixture of both[2]. It may be that different organisms could be found at each of these areas. If this is true then the total tolerance value may be different in that area as well. Davy-Bowker *et al.* found that there was a significantly more benthic macroinvertebrates and families at the head of a riffle compared to the tail[4]. In another similar study Costa, and Melo found that organism abundance and taxa richness was much lower in riffles than in different areas of the same reach such as moss, roots, and pools[5]. It may also be that when a man-made structure is present the results from collection in that area could be very different than when the area is undisturbed. Yu *et al.* found that man-made structures, such as a bridge, cause a negative significant difference in taxa richness and using the Shannon-Wiener index[6]. In a study conducted by Smith and Lamp, it was found that insect communities in urbanized headwater streams were less diverse than rural streams[7]. The results of these studies and other research like this shows that human activity near streams generally has a negative impact on that streams overall ability to sustain aquatic life because of the decline of water quality. If a difference in the tolerance and the water quality is determined whether the difference is good or bad it always poses the question of why a difference exists.

Differences in water quality can occur for a number of reasons. Some of these include: Pollutants (unwanted materials ranging from litter to industrial waste), Sediment (soil erosion), Organic wastes (discharge from processing or treatment plants, mills, and refineries), Nutrient enrichment (excess nitrogen or phosphorous levels that originates from perhaps a fertilizer runoff nearby), temperature elevation (mostly due to the removal or riparian zones which provide shade), channelization (changing the shape of natural streams), toxic chemicals (discharge industrial wastes, indiscriminate use of pesticides, and careless dumping), and point source and nonpoint source pollution[2]. The purpose of this experiment was to determine if differences in water quality occur when a comparison was made between an established reach and an adjacent reach with and without a man-made structure present. The prediction that was made was if a man-made structure was present at or nearby a specific reach then the water quality at that area would have been different than that of an undisturbed reach.

2. Methods

2.1 Study Area Sites

The study areas were both along Lily Cache Creek in Plainfield, Illinois. The first study area was located at the Van Horn Woods East and was accessed from West US 55 Frontage Road. The Van Horn Woods was a woody area providing the study area with a variety of vegetation and approximately 50% canopy cover. The established site reach had a riffle velocity of 0.41 meters per second, had an average depth of 12.2 inches (30.5 cm), and did not contain any man-made structure (Figure 1a). The adjacent site was upstream of the established site. The adjacent reach had a velocity of 0.56 meters per second, was 40 feet wide (12.2 m), a water temperature of 27 degrees Celsius, had an average depth of 16.3 inches (40.8 cm), and contained a small footbridge made primarily of wood and concrete. (Figure 1b) While collection was taking place the stream water at both the established and adjacent sites had no odor and showed medium turbidity. The second study area was at the Four Seasons Baseball Fields West and was accessed from Lockport Street. The established site reach showed slight turbidity, had a width of 22 feet 1 inch (6.725 m), a water temperature of 22 degrees Celsius, had an average velocity of 0.44 meters per second, and an average depth of 7.5 inches (18.75 cm). This area was undisturbed and had submerged aquatic plants with the riparian zone dominated by Reed Canarygrass (Phalaris arundinacea)[8] (Figure 2a). The adjacent site was downstream of the established site and contained a concrete two-lane traffic overpass. This site showed slight turbidity, had a width of 54 feet (16.51 m), a water temperature of 23 degrees Celsius, an average velocity of 0.40 meters per second, and an average depth of 7.2 inches (18 cm). (Figure 2b)

Figure 1. Lily Cache Creek at Van Horn Woods, Plainfield, IL. a. Established Reach with no man-made structure (Left), b. Adjacent Upstream reach with footbridge (Right)

Figure 2. Lily Cache Creek at Four Seasons Baseball Fields, Plainfield, IL. a. Established Reach with no man-made structure (Left), b. Adjacent Downstream reach with vehicle overpass (Right)

2.2 RiverWatch Procedure

Environmental Conditions and factors such as substrate, algae cover, water odor, turbidity, and canopy cover were recorded. The study areas were measured for depth using a meter stick, width using a tape measure, velocity using a timer and Ping-Pong ball, and temperature with a Celsius thermometer. The procedure for collection used during this experiment was the Kick Seine method[9]. Collection began by identifying a riffle area, placing the 500-micron D-net downstream to collect any specimens and sediment, scraping any boulders by hand directly in front of the net then removing or collecting them for further examination, and utilizing the kick method 1 foot (0.3 m) in front of the net, disturbing the substrate to a depth of 3 inches (2.5 cm) for three minutes. The D-net was also used to collect specimens on snags. Snags were scraped at a desired area for approximately 5 – 10 minutes or until desired collection size was acquired. Any debris from the snag was also collected and examined later. After each collection the net was emptied in the 19-liter bucket while using a wash bottle to ensure all visible specimens were emptied into the bucket.

2.3 Macroinvertebrate Sampling

Van Horn RiverWatch and adjacent site collection occurred on 29 March 2018. Four Seasons Baseball Fields RiverWatch and adjacent collection occurred on 7 June 2018, While at Van Horn Woods established site; a riffle was located and the kick seine method was utilized, afterward in that same area a snag was sampled. At the adjacent site organisms were collected at a riffle near the walking bridge utilizing the kick seine method and a snag directly under the bridge was sampled. While at Four Seasons Baseball Fields established site, a riffle was identified and the kick seine method was utilized, then in the same area a snag was scraped. At the adjacent site the kick seine method was utilized in two riffle areas on either side of the traffic overpass and a snag lying half under the bridge was scraped. The samples were transported to the Van Horn Woods immediately following each collection and any identifiable insects were sorted from debris and placed into a pan divided into 12 sections with a small amount of club soda poured in to slow the organism's ability to take in oxygen, which effectively immobilizes the insects without damaging the exoskeleton. The quadrants from which the insects were selected were picked at random by a number generator. The selected insects were placed into a subsample consisting of about 100. The subsamples were placed into small containers with 91% Isopropanol to preserve them during transportation to the laboratory. While at the laboratory macroinvertebrates were identified using a dissecting microscope and identification key, sorted into petri dishes using forceps, and counted. After which the Macroinvertebrate Biotic Index (MBI) was calculated.

2.4 Data Analysis

The Macroinvertebrate Biotic Index (MBI) used to determine stream quality in this study was from the Illinois RiverWatch Protocol- a citizen scientist's initiative. MBI is the total tolerance value of the total tolerance value (ΣTV) divided by the organisms sampled (ΣN). MBI = $\Sigma TV / \Sigma N$[2]. Along with MBI; the taxa richness (total number of taxa identified), EPT taxa (number of EPT taxa present), EPT percentages (the percent of EPT taxa present), pollution intolerant/ tolerant taxa (number of pollution tolerant/ intolerant taxa present), pollution intolerant / tolerant percentages (the percent of pollution tolerant/ intolerant taxa present), and Shannon Diversity index (measure of order diversity) SDI= $-\sum P_i \ln(P_i)$ were all calculated and recorded[2]. During this study pollution intolerant taxa were defined as any taxa that had a tolerance index/rating less than or equal to 5.5 ($TI \leq 5.5$) while pollution tolerant taxa were greater than or equal to 5.5 ($TI \geq 5.5$). Finally Chi-square analysis was performed to compare results and statistical analysis was calculated using a p value of 0.05. ($p \leq 0.05$)

3. Results

When looking at the comparison of the statistical analysis between two sites at the same location, one site with a man made structure present and the other site without a similar structure present, the results showed that there was a significant difference of EPT to non-EPT ($p<0.01$) and pollution tolerant to pollution intolerant ($p<0.01$) organisms between the Four Seasons established site (RiverWatch) and the Four Seasons adjacent site (vehicle bridge site). The MBI rating at the Four Seasons established site was 5.695 (Fair). The MBI at the Four Seasons adjacent site came to be 5.125 (Fair). (Table 1) There was not a significant difference of EPT to non-EPT organisms ($p=0.489$), although, there was a significant difference of pollution tolerant to pollution intolerant organisms ($p=0.010$) between Van Horn established site (RiverWatch) and Van Horn adjacent site (walking bridge site). The MBI rating at the Van Horn established site was 5.368 (Fair). The Van Horn adjacent site came to be 5.005 (Fair when rounded). (Table 1)

Table 1. Results comparing the data of the four study sites in Lily Cache Creek, IL. To determine the effects of man-made bridges (one walking, one traffic) on stream quality determinates.

Site locations	**Van Horn RiverWatch**	**Van Horn Adjacent**	**Four Seasons Riverwatch**	**Four Seasons Adjacent**
Organisms Sampled	129	98	151	148
Taxa Richness	15	16	16	18
EPT Taxa Richness	5	7	4	6
MBI	5.368 (Fair)	5.005 (Fair)	5.695 (Fair)	5.125 (Fair)
SDI	2.353	2.516	2.442	2.466
% EPT Individuals	33.33	37.75	19.86	36.48
% Non-EPT indivduals	66.66	62.24	80.13	63.51
% Pollution Intolerant	50.38	67.34	35.09	54.05
% Pollution Tolerant	49.61	32.65	64.9	45.94

When more comparisons were made between sites that both contained no man-made structure it was found that there was a significant difference of EPT to non-EPT ($p=0.010$) and pollution intolerant to pollution tolerant ($p<0.01$) organisms between the Van Horn established site (RiverWatch) and the Four Seasons established site (RiverWatch). It turned out that when two sites containing structures the Van Horn adjacent site and the Four Seasons adjacent site are compared there is no significant difference of EPT to non-EPT organisms ($p=0.840$), but there was a significant difference in the pollution intolerant to tolerant organisms ($p=0.037$) between those sites. When comparing different locations established sites and adjacent sites this is what was found. There was a significant difference in EPT to non-EPT and pollution intolerant to pollution tolerant organisms between the Four Seasons established site (RiverWatch) and the Van Horn adjacent site (p=0.001, p<0.001 respectively). The Van Horn Established site and Four Seasons adjacent site show no significant difference between EPT to non-EPT and the pollution intolerant to tolerant organisms (p=0.583, p=0.542 respectively). Lastly, when all four sites are compared there was a significant difference of EPT to non-EPT and pollution intolerant to pollution tolerant organisms (p=0.004, p<0.001 respectively).

The results of abundance of EPT and non-EPT at the various sites showed that all of the sites were dominated by non-EPT taxa. (Figure 3) Four Seasons adjacent contained the highest abundance of EPT taxa (54 EPT organisms). Meanwhile, at the same location the Four Seasons established (RiverWatch) site contained the lowest abundance of EPT taxa (30 EPT organisms). (Figure 3) The pollution intolerant and pollution tolerant abundance varied largely among sites. The Four Seasons established (RiverWatch) contained the highest abundance of pollution tolerant taxa (98 Pol. Tol.). (Figure 4) Pollution tolerant taxa were the lowest at the Van Horn adjacent site (32 Pol. Tol.). (Figure 4) Pollution intolerant taxa abundance was highest at the Four Seasons adjacent site (80 Pol. Intol.). (Figure 4) Four Seasons established (RiverWatch) had the lowest abundance of pollution intolerant taxa organisms (53 Pol. Intol.). (Figure 4)

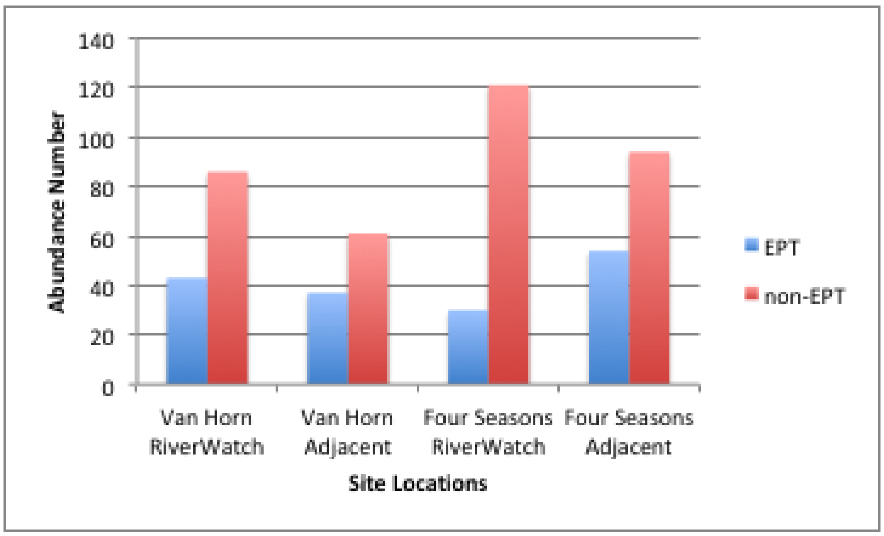

Figure 3. Comparison of EPT to non-EPT macroinvertebrates that were found at each of the four study sites in Lily Cache Creek, IL.

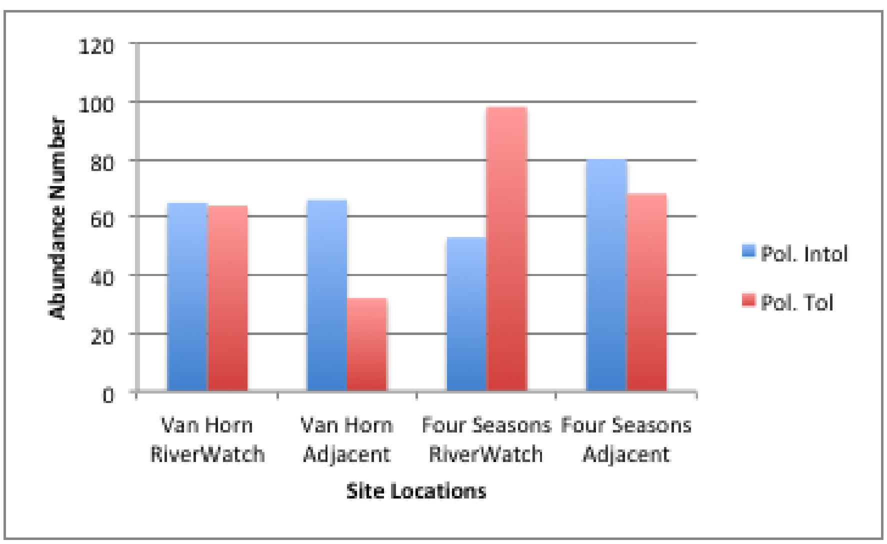

Figure 4. Comparison of pollution intolerant to pollution tolerant macroinvertebrates that were found at each of the four study sites in Lily Cache Creek, IL.

Looking at the Shannon-Diversity index (SDI) between sites it was found that the Van Horn woods established and adjacent sites showed a greater difference in diversity rating than the comparison of the Four Seasons sites. (Table 1) The taxa richness of the Van Horn established and adjacent sites differed by only one taxon (15 and 16 respectively). While the Four Seasons sites differed by two taxa (16 and 18 respectively). (Table 1) The EPT taxa richness at the Van horn established site was found to be 5 taxa, the Van Horn adjacent was 7 taxa, the Four Seasons was 4 taxa, and the Four Seasons adjacent was 6 taxa. (Table 1) The Four Seasons adjacent site seemed to be dominated by Snail Case Caddisfly (O. Trichoptera F. Helicopsychidae), Midge (O. Diptera F. Chironomidae) and Flatworm (O. Turbellaria)[3]. (Table 2) The most abundant taxa at the Four Seasons RiverWatch were the Snail Case Caddisfly, Midge, and Operculate Snail (C. Gastropoda F. Viviparidae)[3]. (Table 2) The Van Horn established site's most abundant taxa were the Midge, Snail Case Caddisfly, Flatworm, and Crawling Mayfly (O. Ephemeroptera F. Tricorythidae)[3]. (Table 2) The Van Horn adjacent site's most abundant taxa were the Operculate Snail, Crawling Mayfly, Midge, and Riffle Beetle (O. Coleoptera)[3]. The most abundant taxon in this study was the Midge making up 17% of the entire number of organism collected. (Table 2)

Table 2. Comparison of the abundance of each taxon present in each of the four study sites in Lily Cache Creek, IL. Total number of organisms from each taxon is included and EPT organisms are highlighted.

	Van Horn adjacent	Van Horn RiverWatch	Four Seasons adjacent	Four Seasons RiverWatch	totals
Flatworm	3	16	18	11	48
Aq. Worm	0	5	6	13	24
Leech	0	6	5	8	19
Sowbug	2	0	0	9	11
Scud	6	10	7	9	32
Broadwing	1	0	1	0	2
Narrowwing	7	4	5	1	17
Swimming	3	0	4	0	7
Clinging	4	2	3	0	9
Crawling	14	16	5	3	38
Stonefly	4	1	0	0	5
Hydropshych	6	0	4	1	11
Snail Case	5	20	35	25	85
Other Cad	1	4	3	1	9
Riffle Beetle	12	3	11	4	30
W.Penny	3	5	2	9	19
Midge	12	29	24	26	91
Blackfly	0	0	5	13	18
Left-Hand	0	3	1	2	6
Operculate	15	5	9	16	45

**Aquatic Worm (O. Oligochaeta), Leech (O. Hirudinea), Sowbug (O. Isopoda), Scud (O. Amphipoda), Broadwinged Damselfly (O. Odonata F.Calopterygidae), Narrowwinged Damselfly (O. Odonata F. Calopterygidea, Lestidae), Swimming Mayfly (O. Ephemeroptera F. Baetidae), Clinging Mayfly (O. Ephemeroptera F. Heptageniidae), Stonefly (O. Plecoptera), Hydropsychid Caddisfly (O. Trichoptera F. Hydropsychidae), Water Penny Beetle (O. Coleoptera F. Psephenidae), Black Fly (O. Diptera F. Simuliidae), Left-Handed Snail (C. Gastropoda F. Physidae)*[3]

4. Discussion

The results of this experiment showed that when waters from two different reaches (established and adjacent) of the same stream no more than 300 feet (61.16 m) apart are compared the overall quality rating (MBI) of the comparisons do not deviate from an MBI rating of Fair. The most noticeable differences between the sites were the comparison of EPT to non-EPT, pollution intolerant to pollution tolerant organisms, and taxa distribution. While Taxa richness, EPT taxa richness, and SDI differed only slightly. The results that occurred of unchanged and even slightly better water quality at adjacent sites with man-made structures nearby goes against the majority of research done by others, which record that the quality of water typically suffers from human interference. More specifically, in the research done by Yu *et al.* there were no pollution sensitive taxa (EPT) found at the study sites which contained man-made structures; the macroinvertebrate community near the bridge abutment in their study was dominated by pollution tolerant taxa such as mollusks and Flatworms (Oligochaeta)[6]. One of the explanations given for this result was that the bridge slowed the water velocity and provided an area for sediment to accumulate allowing for a build up of pollutants and thus decreased the quality of water in that area[6].

There are a few possible explanations for the differences in the results of this experiment and of others. In contrast, the study areas containing the man-made structures in our experiment did not reduce stream velocity, but increased it most likely due to the common cobble and gravel substrate in these areas and narrowing channelization of the stream. Another explanation is the difference in human population size of China and the United States and the amount of disturbance that may come with higher population. Another could be the difference in the number of study sites and the number of organisms collected per sample. A separate factor that might have influenced our results was that we received a heavy amount of rainfall during our experiment, which could have affected the quality of all the sites as a whole from sediment and debris flow from other areas.

The way the taxa were distributed amongst the sites could be clarified through the type of substrate and velocity at that reach. At the Four Seasons adjacent site the velocity of the riffle 0.4 meters per second making it the fastest riffle out of all four of the study sites. In addition to the fastest riffle it was also the site with the highest taxa richness. These findings agreed with other research like Schoen *et al.* when studying velocity as a factor in determining macroinvertebrate assemblages they found that faster water velocity is a major factor in shaping macroinvertebrate communities; thus, a greater number of taxa can be found in faster water velocity areas[10]. Not only did the results show the correlation of velocity and taxa but they also showed a similar relationship between the size (width) of the stream and that streams taxa richness and distribution. In a study performed by Heino *et al.* it was found that in general as stream size went up the number of taxa increased as well they also found that taxa distribution was more even as stream size increased[11]. The results of this research agrees with Heino *et al.* on both accounts of taxa richness and diversity in the larger study sites which are the Van Horn adjacent and the Four Seasons adjacent sites.

Because our study included only four sites in two locations of the same creek, the adjacent site at each location containing a man-made structure, the established sites at each location were compared to look at a pure established and adjacent comparison. Interestingly, (although all the sites received a MBI rating of Fair) the biotic index ratings of the sites that contained a man-made structure at both adjacent sites were slightly better than both of the established sites, which were undisturbed. The taxa richness was especially interesting when comparing the Van Horn adjacent site and the Four Seasons established site because the richness was the same between these two sites. It also is true that The Four Seasons established site contained the highest number of pollution tolerant organism and the lowest EPT taxa richness. This clearly means that taxa richness is not affected by water quality. Despite this, many other studies show that taxa richness declines as pollution increases while organism abundance increases. In fact, in Adakole and Anunne's research they found exactly that; as organic pollution increased macroinvertebrate species richness decreased while species density increased[12].

When just looking at the differences of the statistical analysis between upstream and downstream organisms the data showed the downstream sites had no significantly different organisms. In fact the downstream sites were the only sites that showed no significant difference in both the EPT and pollution intolerant/ tolerant organisms. Meanwhile, the upstream sites did have significantly different organisms. This could mean that the downstream organism in a creek could be a good constant when comparing and rechecking data. More research should be conducted to further evaluate the comparison of adjacent reaches and man-made structures effects on stream life and quality. In conducting similar studies future research could benefit from a larger subsample size, collecting a whole sample instead of a subsample, more study areas, more locations in possibly other nearby bodies of water, looking at weather patterns and conducting research when optimal weather is expected, looking at higher levels of organization, sampling during different seasons, and possibly greater distance between study sites at the same location.

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