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MACROINVERTEBRATES AS AN INDICATOR OF WATER QUALITY IN WHITE CLAY CREEK

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ABSTRACT

Since the late 1800s, Pennsylvania's rivers and streams have been stocked with trout to boost recreational opportunities and supplement wild populations. In 2015, PFBC started the Keystone Select Stocked Trout Waters Program to create enhanced trout fishing opportunities in every region, selecting the Middle Branch of White Clay Creek as part of the program for the Southeast region. Streams that enter the program should be able to support trout populations of 250 per mile or more. This study focused on whether the water quality of White Clay Creek's Middle Branch exceeded that of its East Branch and main stem. This study calculated species richness, EPT index, and pollution tolerance index to determine water quality in the main stem, Middle Branch and East Branch. EPT index revealed no significant difference, but species richness data revealed a difference between the main stem and East Branch as well as between the Middle Branch and East Branch. Pollution tolerance index was lowest at the East Branch indicating poorer water quality. However, no difference could be drawn from the data between the Middle Branch and main stem.

Key words: Macroinvertebrates, EPT Index, Water Quality, Species Richness, Pollution Tolerance Index

INTRODUCTION

Since the late 1800s, the Pennsylvania Fish and Boat Commission (PFBC) has stocked trout in Pennsylvania's rivers and streams. Trout stocking has supplemented native and wild populations while also enhancing recreational opportunities for anglers (Weber et al., 2010). PFBC stocks between 3.2 and 5.7 million trout annually, with the purpose of establishing self-sustaining trout populations in every stocked stream (Weber et al., 2010). In 2015, the PFBC created the Keystone Select Stocked Trout Waters Program (Pennsylvania Fish and Boat Commission, 2020). The program includes twenty-three trout streams in PA that have the ability to support 250 trout per mile of stream and provide angling opportunities year- round (Pennsylvania Fish and Boat Commission, 2020). Every year, 9,500 adult size trout (2-3 years old and over 14 inches in length) are stocked in these streams (Pennsylvania Fish and Boat Commission, 2020). The program intends to establish destination fisheries in every PFBC region while also working to enhance the aquatic ecosystems found in these streams. Included in this program is the Middle Branch of White Clay Creek in southeastern Chester county.

A study done in 2008 found that the majority of White Clay Creek could be considered of fair or poor water quality (Stroud Water Research Center, 2016). The 2008 study used macroinvertebrates as indicators of water quality. Macroinvertebrates exist as a cost-effective and scientifically accepted tool for measuring water quality because they have a diverse assemblage and as a group are sensitive to environmental stressors (Stroud Water Research Center, 2016). White Clay Creek, designated as a Wild and Scenic River in 2000, provides habitat for a rich diversity of fish and wildlife species. Despite being of significant recreational and ecological value, White Clay Creek's water quality deteriorates dramatically in the lower part of the watershed (Stroud Water Research Center, 2016). Degradation of water quality in White Clay Creek can be linked to human uses of land in the water shed, as a majority of the land has

been developed either for residential or agricultural purposes.

This study intends to draw off of the previous study by using macroinvertebrates to evaluate water quality in White Clay Creek. This study will compare macroinvertebrate communities found in the Middle Branch, East Branch, and main stem of White Clay Creek. The PFBC stocks larger trout in the Middle Branch as part of the Keystone Select Stocked Trout Waters program, possibly indicating that the Middle Branch is of higher quality than the East Branch and main stem. If the Middle Branch has higher water quality than the East Branch and main stem, then water quality indices (species richness, EPT index, pollution tolerance index) will be higher in the Middle Branch. This information could help the PFBC in management decisions involving which streams should be included in the program and which should be left out. With the program seeking to establish destination fisheries, this information could be particularly valuable.

FIELD SITE

This study took place at three locations on White Clay Creek, with five sites being sampled at each location. All locations exist in southeastern Chester County, Pennsylvania and are part of the White Clay Creek system within the boundaries of White Clay Creek State Preserve. Sampling locations were on the Main Stem, East Branch, and Middle branch of White Clay Creek. The Main Stem had a temperature of 8.3^{o}C and consisted of mainly gravel and rocky substrate with an average canopy density of 16.677%. The East Branch had a temperature of 8.9^{o}C and consisted of mainly gravel and silt substrate with an average canopy density of 2.887%. The Middle Branch had a temperature of 7.2^{o}C and consisted of entirely rocky substrate with an average canopy density of 10.798%. Sampling on the Main Stem took place below the convergence of the East and Middle Branches.

MATERIALS AND METHODS

Sampling methods for this study were based on the sampling methods used in BI 121 lab and General Ecology lab. At each of the three locales, five sampling sites (fifteen in total) were randomly chosen for sampling. At the first site of each location, temperature and GPS location were recorded. All sites were measured for canopy density and the type of substrate being sampled. The University of New Hampshire's iPhone app, CanopyApp, was used to measure canopy density. Kick netting methods were used to sample macroinvertebrates, with each site being kick netted for one minute at a time. Once a site had been sampled, the resulting collection would be dropped into a bin of water brought to the sampling location. Macroinvertebrates from the sample were separated into cups and identified to the order level with the number counted being recorded. A macroinvertebrate identification key from Stroud's Water Research Center was used as an aid in identifying macroinvertebrates. Once all macroinvertebrates collected had been recorded, the macroinvertebrates were then returned to the water. Two of the locations (the East Branch and Main Stem) were sampled during the closed trout season to ensure the substrate had not been previously disturbed by anglers. The Middle Branch belongs to the Keystone Selected Trout Waters program and remains open to fishing year-round, so anglers were present at the time of sampling. Once the data had been collected, data analysis on the macroinvertebrates collected could take place. Species richness, EPT index, and pollution tolerance index were calculated to assess water quality between the locations, with it being hypothesized that the Middle Branch will have the best water quality. Species richness and EPT index were compared between streams using an ANOVA single factor test and pollution tolerance index was used to determine if the water quality at the locations could be considered good, fair, or poor. EPT index was calculated at each sampling site using the method prescribed by the USDA ((McQuaid, 1999).

Pollution tolerance index was calculated using the same method described in BI 121 lab. Each macroinvertebrate species was counted to determine abundance. An abundance of 1-9 scores as rare, 10-99 scores as common, and over 100 scores as dominant. The species were then separated into sensitive (example: mayflies, stoneflies, caddisflies), somewhat sensitive (example: crane flies, sow bugs, clams), and tolerant (example: midge flies, aquatic worms). The number of species deemed rare, common, or dominant were then multiplied by a coefficient that varied based on tolerance and abundance. For sensitive species, coefficient values were 5.0 for rare, 5.6 for common, and 5.3 for abundant. For somewhat sensitive species, coefficient values were 3.2 for rare, 3.4 for common, and 3.0 for dominant. For tolerant species, coefficient values were 1.2 for rare, 1.1 for common, and 1.0 for dominant. The values were then added up for each tolerance category to determine a final PTI score. Scores less than 20 indicate poor water quality, between 20 and 40 indicate fair water quality, and above 40 indicate good water quality.

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RESULTS

After the macroinvertebrates had been collected and recorded, statistical analysis of the data began. EPT index was measured from each site's sample (table 1) and then compared using an ANOVA single factor test (table 2) to determine if any significant difference existed between the three sampling locations. In total, sixty-nine specimens of Trichoptera, Ephemeroptera, and Plecoptera were found across the fifteen sampling sites.

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Table 1: EPT index calculated at each site. Classification were determined by the EPT value, 0-6 indicates poor water quality, 7-13 indicates fair quality, 14-20 indicates good-fair quality, 21-27 indicates good quality, and over 27 indicates excellent quality. MS WCC site 4 was considered to be good-fair quality; MB WCC site 10 and MS WCC site 5 were considered to be of fair quality. All other sites rated as poor. Mean and standard deviation are included at the bottom

EPT Index			
Site Number	MS WCC	EB WCC	MB WCC
1	4	4	3
2	4	6	4
3	1	1	3
4	20	0	10
5	7	0	2
Mean	7.2	2.2	4.4
Standard Deviation	7.5	2.7	3.2

Table 2: ANOVA single factor test on EPT indices from table 1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62.8	2	31.4	1.286885	0.311642	3.885294
Within Groups	292.8	12	24.4			
Total	355.6	14				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
MS WCC	5	36	7.2	55.7
EB WCC	5	11	2.2	7.2
MB WCC	5	22	4.4	10.3

The above ANOVA single factor test calculated a p-value of 0.31 and an F-value of 1.29, indicating that the data derived from calculating EPT indexes showed no significant difference between locations. The Main Stem and Middle Branch had averages of 7.2 and 4.4 respectively, higher than the average of 2.2 calculated from the East Branch. Variances in the Main Stem and Middle Branch were calculated at 55.7 and 10.3 respectively, also higher than that of the East Branch at 7.2. Standard deviation was also high in the main stem at 7.5. In the Middle and East Branch standard deviation was calculated to be 3.2 and 2.7 respectively. Two outliers may exist in the data, twenty at site 4 on the Main Stem and ten at site 4 on the Middle Branch.

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Species richness is shown below between the three sampling locations (table 3).

Table 3: Species richness measured at each site of the three locations. The standard deviation of the data is given at the bottom of the table

Species Richness			
Site	MS WCC	EB WCC	MB WCC
1	6	5	5
2	7	4	4
3	5	4	4
4	6	4	6
5	4	2	6
Mean	5.6	3.8	5.0
Standard Deviation	1.14	1.10	1.00

Table 4: ANOVA test done on the species richness data collected at each site as shown in table 3.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
MS WCC	5	28	5.6	1.3
EB WCC	5	19	3.8	1.2
MB WCC	5	25	5	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.4	2	4.2	3.6	0.059605	3.885294
Within Groups	14	12	1.166667			
Total	22.4	14				

The above ANOVA test comparing species richness calculated a p-value of about 0.06 and an F-value of 3.6. Variances at main stem, East Branch, and Middle Branch were calculated to be 1.3, 1.2, and 1.0 respectively and standard deviation was calculated to be 1.14, 1.10, and 1.00 respectively. The p-value is just over the 0.05 threshold indicating that a significant difference may exist in the data. Table 5 below shows the results of a t-test done between the main stem and the East Branch, the East Branch and the Middle Branch, and the main stem and the Middle Branch.

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Table 5: results of a two-sample t-test assuming equal variance between all the locations. This was done to determine any statistical difference between the main stem and Middle Branch, the East Branch and Middle Branch, and the main stem and East Branch. The p-values calculated were the most important factor id determining in a statistical difference existed.

	MS WCC	*MB WCC*		*EB WCC*	*MB WCC*		*MS WCC*	*EB WCC*
Mean	5.6	5	Mean	3.8	5	Mean	5.6	3.8
Variance	1.3	1	Variance	1.2	1	Variance	1.3	1.2
Observations	5	5	Observations	5	5	Observations	5	5
Pooled Variance	1.15		Pooled Variance	1.1		Pooled Variance	1.25	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	8		df	8		df	8	
t Stat	0.8846 5		t Stat	- 1.80907		t Stat	2.54558 4	
P(T<=t) one-tail	0.2010 7		P(T<=t) one-tail	0.05402 2		P(T<=t) one-tail	0.01720 5	
t Critical one-tail	1.8595 5		t Critical one-tail	1.85954 8		t Critical one-tail	1.85954 8	
P(T<=t) two-tail	0.4021 5		P(T<=t) two-tail	0.10804 5		P(T<=t) two-tail	0.03441	
t Critical two-tail	2.306		t Critical two-tail	2.30600 4		t Critical two-tail	2.30600 4	

The t-test calculated a p-value of 0.201 between the main stem and Middle Branch, a value of 0.054 between the East Branch and Middle Branch, and a value of 0.017 between the main stem and the East Branch. This indicates that some significant differences may exist in the data. Table 6 below shows PTI scores calculated for each sampling location.

Table 6: Pollution tolerance index (PTI) values for all locations. A value above 20 indicates fair water quality while a value below twenty indicates poor water quality. Values greater than 40 would indicate good water quality.

	MS WCC	EB WCC	MB WCC
PTI	28.3	17.8	21.3

The Middle Branch score of 21.3 and the main stem score of 28.3 indicates fair water quality. The East Branch value of 17.8 indicates poor water quality.

DISCUSSION

EPT index measures the number of mayflies (*Ephemeroptera)*, stoneflies (*Plecoptera)*, and caddisflies (*Trichoptera)* found at each sample site. At White Clay Creek, a maximum EPT index of 20 was calculated at the main stem and a minimum EPT index of 0 was found at the East Branch. However, 20 may be an outlier in the data as the main stem had a high variance of 55.7. The ANOVA test comparing EPT index between the three locations calculated a p-value of 0.3, showing that no significant difference can be derived between locations for EPT index. Despite averaging a higher EPT index (7.2), the main stem has too much variation to have a significantly different EPT index from the Middle or East Branch. The Middle Branch also averages higher than the East Branch, an average of 4.4 compared to 2.2. However, both have relatively high variance, 10.3 and 7.2 respectively. Because of such high variances existing, the data cannot be considered significant and does not indicate possible differences in stream quality.

Species richness calculated at each site revealed lower variances of 1.3 at the main stem, 1.2 at the East Branch, and 1.0 at the Middle Branch. Standard deviations were also calculated at 1.14, 1.10, and 1.00 respectively. This indicates that the data of each site does not deviate much from the average. The ANOVA test done to compare species richness between the sites produced a p-value of 0.0596. Generally, the cutoff is 0.05, but when using ecological systems 0.1 sometimes can be considered significant. Because the p-values were close to 0.05, a significant difference may exist between the streams. T-tests were run to determine if there were differences

between streams. The test for the main stem and East Branch produced a p-value of 0.017 indicating that a significant difference exists between the main stem and East Branch for species richness. Between the Middle Branch and East Branch, the t-test produced a p-value of 0.054 indicating a possible difference in the data for species richness. Between the main stem and Middle Branch, the p-value was 0.20 indicating no difference. The differences in species richness found between the East Branch and the other two sampling locations indicate that the East Branch may have poorer water quality than the others. The average species richness at the East Branch was 3.8 while the main stem averaged 5.6 and the Middle Branch measured 5.0 species per site.

Pollution tolerance index (PTI) uses macroinvertebrates to assess water quality in a stream. The PTI scores of the main stem, East Branch, and Middle Branch were measured at 28.3, 17.8, and 21.3 respectively. This indicates fair water quality in the main stem and Middle Branch, and poor water quality in the East Branch. This fits the findings from tests done on species richness that the East Branch water quality is less than that of the main stem and Middle Branch. This also matches the findings of the 2008 study done by Stroud's Water Research Center. This study found that the East Branch had poor water quality within White Clay Creek Preserve while the main stem and Middle Branch had fair water quality.

The results did not support the initial hypothesis that the Middle Branch would have better water quality as part of being a keystone select trout stream. However, the Middle Branch did have better water quality than the East Branch, but no difference could be drawn between the Middle Branch and main stem. More research should be done on White Clay Creek in testing for water quality parameters. This study was limited in technology and could not test for pH, conductivity, dissolved oxygen, and total dissolved solids. Anthropogenic impacts on White Clay Creek water quality are not fully understood and require additional research to understand.

Findings suggest that the main stem may also be suitable for the keystone select program. The PFBC could use information similar to what was found in this study in making further assessments in which streams enter the program. This could provide information for bettering Pennsylvania's trout habitat and improving trout streams to create greater recreation opportunities for trout fishing in Pennsylvania.

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