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Stream Assessment on the Impact of Agricultural Activity in the Dry River, VA

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ABSTRACT

Stream bioassessments using macroinvertebrate population dynamics is a technique that determines water quality in natural aquatic environments based on the taxa found at the site. The aim of this study is to determine if agricultural activity in Rockingham County, VA has an impact on water quality in Dry River. Stream quality was evaluated by sampling and identifying macroinvertebrate taxa at various sites above and below disturbances. Each macroinvertebrate was ranked from 1-10 based on pollution tolerance or intolerance using the Biological Monitoring Working Party Index. The results in this study indicate that agricultural activity does impact the water quality in Dry River in Virginia.

Keyword: macroinvertebrates, agriculture, pollution, Dry River, stream quality

INTRODUCTION

The Dry River begins in the George Washington National Forest and flows through the Shenandoah Valley in Southwest Virginia. It is home of many aquatic and terrestrial organisms including fish and bird species that use the Dry River habitat. Dry River provides a great trout fishery in Virginia and holds rainbow, brown, and brook trout (Authors personal observations). The Virginia Department of Game and Inland Fisheries stock various locations throughout Dry River (VDGIF stocking website) to facilitate this recreational fishery. Migrating birds also use Dry River Valley. Therefore, Dry River becomes a recreational opportunity that adds ecotourism opportunities that create revenue for the small towns and cities that run its length. Rockingham County, which Dry River flows through, is the leading poultry-producing county in Virginia (Bosch and Napit 1992). Along with poultry production in Virginia, Rockingham County is the leading producer of corn silage, dairy cattle, hay, alfalfa, and ranks the highest in farm income (Pease and Kenyon, 1992). The high percentage of land use in agriculture that surrounds the Dry River could affect water quality and environmental integrity.

In the last 40 years, antipollution laws have reduced discharge of point source pollution of toxic substances into freshwater (Howarth et al., 2000). However, less effort has been made to restrict non-point source pollution of nitrogen (N) and phosphorus (P) that enter freshwater from agricultural and urban runoff (Howarth et al., 2000). Agriculture can affect aquatic ecosystems through the run-off of fertilizers, manure, and pesticide applications (Pease and Kenyon, 1992). Livestock can overgraze riparian areas, creating a loss of stability to streambanks, which causes soil erosion, and overall declining water quality (Belsky et al., 1999). Inputs of nonpoint pollutants from agriculture have increased dramatically and now N and P represents the largest pollution problem facing freshwater as well as the coastal waters (Howarth et al., 2000). Consequently, agriculture can impact natural aquatic ecosystems negatively and ecosystems can become biologically imbalanced (Moss, 2008).

Nutrient over-enrichment of aquatic ecosystems can trigger ecological imbalance that decrease the biological diversity (Howarth et al., 2000).This imbalance can affect aquatic species which has caused fish kills and advisories in neighboring rivers such as the Shenandoah, New, and Roanoke Rivers. During the past couple decades research has found phosphorus to be the biggest driver of eutrophication of freshwater systems (Howarth et al., 2000). High levels of nitrogen and phosphorus in the water harm both vertebrate species and invertebrate species. Fish that are in contact with high nutrient levels affect cardiovascular processes, behavior, endocrine system, and excretory processes (Kuklina et al., 2013). Invertebrate species, when living in a high nutrient environment, are affected through the loss of locomotive abilities, cardiac distress, and unusual behavior (Kuklina et al., 2013).

Plant communities are also impacted by nutrient additions. Aquatic plant communities are the basis for a healthy and diverse aquatic ecosystem, providing food, shelter, and breeding habitats for aquatic species (Withers and Lord 2002; Mainstone and Parr 2002). Nutrient enrichment in freshwater systems can degrade plant community by altering the competitive balance between different aquatic plant species (Mainstone and Parr 2002). Diffuse sources of phosphorus, particularly from agriculture, are a major contributor to phosphorus levels in riverine sediments, where it can be utilized by benthic algae and rooted plants. This phosphorus can also be released into the water column by a variety of processes (Mainstone and Parr 2002).

Testing water quality can be completed using equipment to measure pH, turbidity, nitrates, phosphates, and dissolved oxygen (Kuklina et al., 2013). Water quality can also be tested with bioindicator species such as macroinvertebrates due to their sensitivity to pollutants. Bioindicator species are often used because macroinvertebrates are a good indicator of the cumulative effects of pollution (Lenat, 1984). In a study of the Ontario stream system (Marsh and Waters, 1980), two branches were surveyed for macroinvertebrates. There was a branch with high agricultural land use in the drainage and a branch with no agricultural land use in the drainage. They found that the branch with high input of agricultural drainage showed a decrease in taxa richness of intolerant groups (*Plecoptera*, *Ephemeroptera*, and *Trichoptera*) and an increase in taxa richness of tolerant groups (*Coleoptera*, *Odonata*). The presence and tolerance level of macroinvertebrates showed that agricultural drainage from nearby farms was negatively affecting the Ontario stream's water quality (Marsh and Waters, 1980).

The goal of this study is to investigate whether water quality in the Dry River is being affected by the agricultural activity. It is important to have water quality assessment to determine water impairment of an aquatic environment which potentially needs management, alternative forms of fertilization, and/or different methods of soil treatment. A healthy stream is vital for both health and economic usage of the waterway, which boosts local and state economies through consumer interaction and licensing.

METHODS

Macroinvertebrates were sampled in the Dry River located in Rockingham County, VA. The Dry River starts from Skidmore Lake located in the George Washington and Jefferson National Forests and ends entering the North River in Dayton, VA. Macroinvertebrates were sampled along US. Route 33 at Riven Rock State Park (Location AA) and in Dayton, 100 meters above the junction to the North River (Location BA). Location AA exists above agricultural activities including dairy and beef cattle farming, poultry broilers and layers, and corn and soybean fields. Location BA is located below these agricultural activities.

Sampling was conducted between April and June of 2017 using the Surber sampling method. Location AA and BA were sampled once a day in April, May, and June. Each sampling day consisted of three isolated locations within sites AA and BA. Within the river the sampling was performed in fast flowing water and a usable substrate for Surber sampling purposes. At each of the sampling points (3 within AA and BA) three Surber samples were taken and combined for each point location (3) within AA and BA. The sampler was firmly placed in the substrate and the substrate was disturbed. The duration of disturbance varied based on substrate characteristics. The goal was to obtain all macroinvertebrates within the sampling area. Each macroinvertebrate was then carefully placed in a 33cm X 21cm aluminum pan and identified to the lowest taxonomical level possible. Each individual was identified using the macroinvertebrate key created by Birmingham et al., (2005).

These data were analyzed using the modified version of the Biological Monitoring Working Party index (BMWP) (Uherek and Gouveia, 2014). The BMWP was used to score taxa from 1-10 and the respective scores were used to determine Average Score Per Taxa (ASPT) at their respective sample locations. To get the score, each organism is given a number according to the BMWP scoring system (Uherek and Gouveia, 2014; See Appendix 1). A total score is calculated for each site and divided by the number of species to obtain the ASPT. Percent EPT was also used to provide another data point to indicate aquatic system health. EPT can be expressed as a percentage of the sensitive orders (E= *Ephemeroptera*, P= *Plecoptera*, T= *Tricoptera*) to the total taxa found. A large percentage of EPT taxa indicates high water quality. The ASPT results (dependent variable) and percent EPT (dependent variable) were analyzed to the differences between sites (independent variable). Shapiro-Wilk test was performed to test normality in the data before the statistical analysis. The ASPT scores were found to be normal and analyzed for significance using a t-test assuming unequal variance. Percent EPT for sites were compared using z-test statistics (Uherek and Gouveia, 2014).

RESULTS

Sample results included 258 individuals belonging to 11 different taxonomic groups. Table 1 depicts species order and relative abundance at each location. According to the scoring parameters of the BMWP, above agricultural activity sites (AA) scored a 48 and below agricultural activity sites (BA) scored a 47 (Table 3). In the study by Uherek and Gouveia (2014) these totals were used to characterize water quality. Table 2 presents data on stream quality based on overall score from taxa. According to Table 2, each site would be considered Class III with scores of 48 (AA) and 47 (BA) falling between the 36-60 BMWP score range. This classification indicates that water quality is questionable and has been moderately impacted. According to this ranking system used by Uherek and Gouveia (2014), Location AA and BA are not significantly different in water quality characteristics. However, this study and sample sites did not produce large numbers in species abundance or species richness. Therefore, statistical importance can be shifted to an ASPT statistic and analysis conducted to further investigate significant difference between each site.

The BMWP scoring parameters were used to determine ASPT. The ASPT for AA was 8 and 5.2 for BA. There is a significant difference in ASPT between the two primary test sites (p-value=0.039, T = 1.89) (Figure 1).

AA sites had 75 individuals that belonged to EPT taxa and BA sites respectively had 24 individuals. Percent EPT for AA was 62.5% and 17.4% for BA. There was a significant difference between these percentages ($z=7.43$, $\alpha=1.96$, $z>1.96$) (Figure 2). According to these results, there is a significant difference between water quality above agricultural activity and below agricultural activity in the Dry River, VA.

DISCUSSION

According to this study, agricultural activity does influence water quality in the Dry River. The relative water quality of above agricultural sites (AA) were better that of below agricultural sites (AA) indicating a negative impact of agricultural activities. There is a plethora of research that supports the notion of negative impacts of agricultural activities in river pollution (Strokal et al., 2016; Howarth et al., 2000; Ribbe et al., 2008; Mainstone and Parr 2002). Some of the major problems with agricultural pollution is the identification of sources and the impacts of agricultural pollution (Ongley, Xiaolan, and Tao 2010; Quan and Yan 2002; Shortle and Abler 2001; Chambers and Quiggin 1996). Restricting non-point source pollution is very difficult because it is hard to identify the source of the pollution (Howarth et al., 2000). The agricultural pollution usually comes in the form of nutrient pollution (Howarth et al., 2000; Ongley, Xiaolan, and Tao, 2010). However, the amount of nutrients from each farm varies based on the season and location (Liu, Wu, and Zhang, 2005). This variation impacts biota in different ways and identification of those impacts are challenging (Howarth et al., 2000).

The importance of water quality bioassessment begins with the health and safety of individuals and the affected environment. The results show agriculture influences water quality; however, the severity is not fully understood. Future studies would need to be performed to uncover the potential impacts and the temporal and spatial variation of such impacts. The impact on water quality, due to agriculture, could potentially affect not only macroinvertebrates but also other species in the food web such as fish and birds. This could affect the local economy by a decrease in fisherman and ecotourism. Farmers and landowners should be made aware of the impacts to water quality for hopes that pristine or better conditions may be obtained.

Further research should be focused on discovering what pollution is in the stream that is affecting macroinvertebrates. Macroinvertebrates are a great bioindicator (Birmingham et al., 2005; Hilsenhoff, 1988), but they do not tell us what impacts are occurring. This would provide insight on the severity of water quality impacts by agricultural disturbances. Once the chemical composition is obtained, the direct source could be identified, and pollutants potentially minimized.

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Table 1. Sampling results from each location showing common name, species taxonomic order, and abundance.

Dry River (above AD)	**Order**	**Species Richness**
Caddisfly	*Trichoptera*	30
Stonefly	*Lecoptera*	36
Helgramite	*Megaloptera*	15
Damselfly	*Odonata*	19
Mayfly	*Ephemeroptera*	9
Crawfish	*Decapoda*	11
	Total	120

Dry River (below AD)	***Order***	**Species Richness**
Aquatic Worm	*Oligochaeta*	28
Crayfish	*Decapoda*	8
Water Penny	*Coleoptera*	23
Caddisfly	*Trichoptera*	11
Midge	*Diptera*	32
Stonefly	*Plecoptera*	13
Helgramite	*Megaloptera*	5
Snail	*Mollusca*	16
Backswimmer	*Notonectidae*	2
	Total	138

Table 2. Water quality interpretation table according to Uherek and Gouveia (2014). Site AA shows a score of 48 and site BA shows a score of 47. Each site would be considered class III meaning water quality is moderately impacted (Uherek and Gouveia 2014).

Class	BMWP score	Category	Interpretation
I	101-150, >150	Good	Very clean water and not significantly impacted
II	61-100	Acceptable	Clean but slightly impacted
III	36-60	Questionable	Moderately impacted
IV	15-35	Critical	Polluted or impacted
V	<15	Very Critical	Heavily polluted

Table 3. This table depicts all sites samples at AA and BA. BMWP totals are depicted on the right and each X indicates if the species was present at the location (Uherek and Gouveia, 2014).

Location (AA)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Points**
Coleoptera										
Decapoda		X	X	X		X		X		6
Diptera										
Ephemeroptera	X		X	X			X			10
Megaloptera		X	X		X	X	X	X	X	4
Mollusca										
Notonectidae										
Odonata	X		X	X	X	X			X	8
Oligochaeta										
Plecoptera	X	X	X	X	X		X	X	X	10
Trichoptera	X	X	X	X	X	X	X	X	X	10
									TOTAL	**48**
									ASPT	**8**
Location (Below AG)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Coleoptera	X		X		X	X	X		X	5
Decapoda		X		X		X		X		6
Diptera	X	X	X	X	X	X	X	X	X	5
Ephemeroptera										
Megaloptera	X		X		X					4
Mollusca		X	X	X	X					3
Notonectidae				X						3
Odonata										
Oligochaeta	X	X	X	X		X	X	X	X	1
Plecoptera			X			X		X		10
Trichoptera			X				X		X	10
									TOTAL	**47**
									ASPT	**5.2**

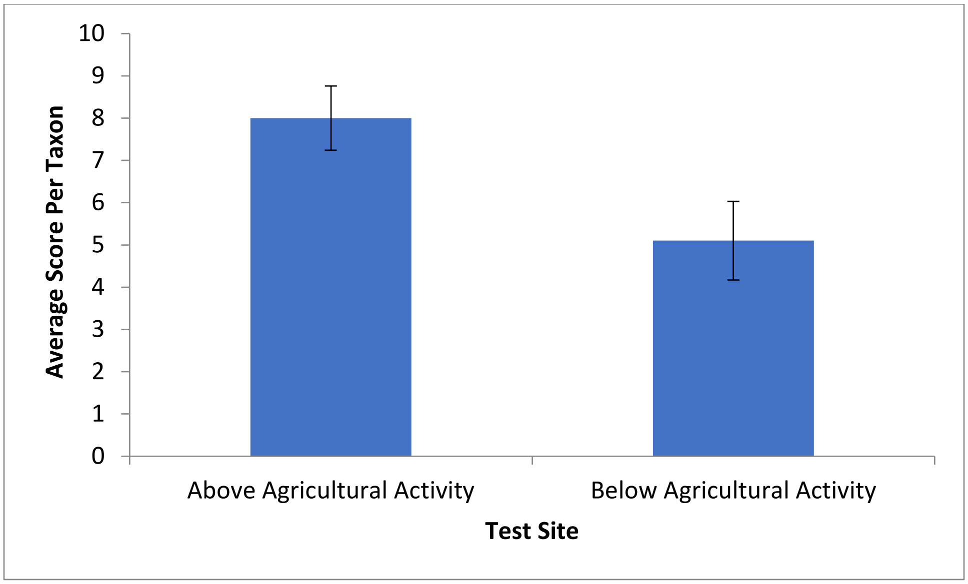

Figure 1. Average score per taxa (ASPT) between the two primary sample sites: Above agricultural activity (AA) (AA=8, SE=0.76), below agricultural activity (BA) (BA=5.2, SE= 0.93) (p-value=0.039, T = 1.89).

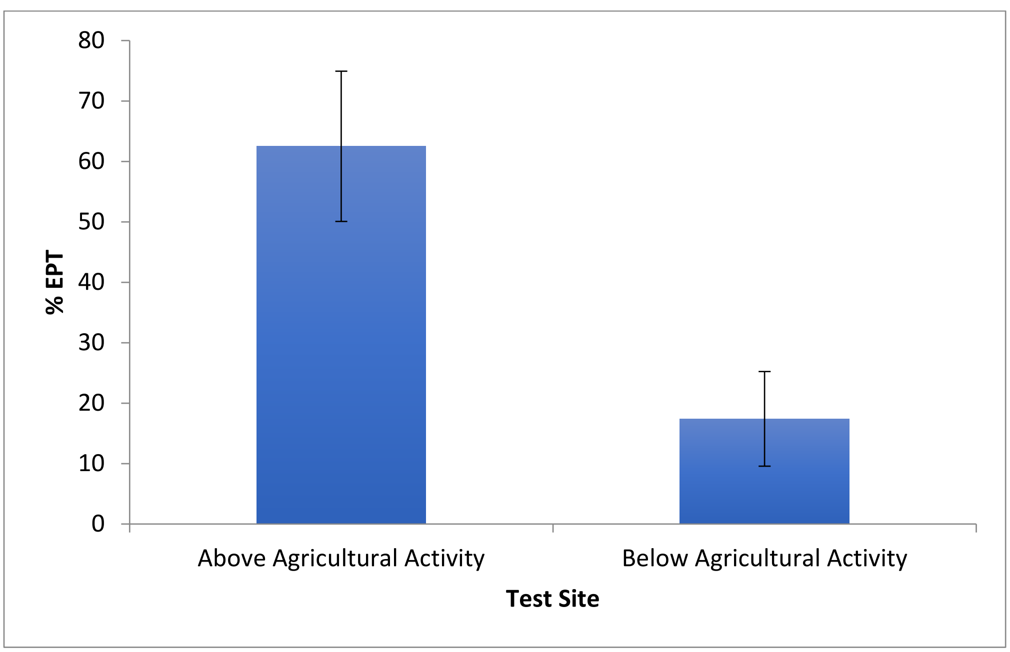

Figure 2. Percent EPT at each test site. Test site AA %EPT=62.5, SE=12.43, Test site BA %EPT=17.4, SE=7.83, Statistical analysis (z=7.43, α=1.96, z>1.96).

Appendix 1

Table. Scoring Index used from the modified version of the Biological Monitoring Working Party (BMWP) from Uherek and Gouveia (2014).

Taxa	Score
Ephemeroptera: *Leptophlebidae, Leptohyphidae.* ***Plecoptera:*** *Perlidae* ***Trochoptera:*** *Brachycentridae, Leptoceridae, Odontoceridae, and Sericostomatidae.*	10
Odonata: *Coenagrionidae, Calopterygidae, Gomphidae, and Libellulidae.* ***Trichoptera:*** *Calamoceratidae, Glossosomatidade, Philopotamidae, and Pschomylidae.*	8
Plecoptera:*Nemouridae.* ***Trichoptera:*** *Polycentropodidae.*	7
Crustacea. Trichoptera: *Hydrobioxidae, Hydroptilidae.*	6
Coleoptera: *Elmidae, Dryopidae.* ***Diptera:*** *Simuliidae, Tipulidae.* ***Ephemeroptera:*** *Euthyplociidae, Polymitarcidae.* ***Platyhelminthes. Trichoptera:*** *Helicopschidae, Hydropschidae.*	5
Arachnida:*Hydracarina.* ***Coleoptera:*** *Chrysomelidae, Curculionidae, Dixidae, Dolichopodidae.* ***Diptera:*** *Anthomyiidae, Ceratopogonidae, Chaoboridae, Dixidae, Dolichopodidae.* ***Empididae:*** *Limoniidae, Psychodidae, Stratiomyidae, and Tabanidae.* ***Ephemeroptera:*** *Bactidae, Caenidae.* ***Megaloptera:*** *Corydalidae, Stalidae.*	4
Annelida: *Hirudinea.* ***Coleoptera:*** *Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae, and Noteridae.* ***Hemiptera:*** *Belostomatidae, Corixidae, Gerridae, Hydrometridae.* ***Mesoveliidae:*** *Naucoridae, Nepidae, Notonectidae, Pleidae, and Veliidae.* ***Mollusca.***	3
Diptera: *Chironomidae, Culucidae, Ephydridae, Muscidae, and Thaumaleidae.*	2
Annelida: *Oligochaeta.* ***Blattaria:*** *Blattidae.* ***Diptera:*** *Sciomyzidae, Syrphidae, and Rhagionidae.* ***Lepidoptera.***	1