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The relationship between riparian zone width and floristic quality in Shenandoah County, Virginia

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The Relationship Between Riparian Zone Width and Floristic Quality in Shenandoah County, Virginia

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Abstract

Riparian zones harbor an above average plant biodiversity. This biodiversity is threatened by invasive species and increasing human disturbance, the latter of which includes deforestation from agriculture and urban development. In this study, I examine relationship between the width of a forested riparian zone and the vegetation growing there. By using floristic quality assessment as a measure of anthropogenic disturbance, one can determine if wider riparian zones foster exclusion of non-native species while providing higher quality habitats for native plants. A randomized block design was used with three forested riparian treatments: deforested, moderately forested (woody vegetation <50m wide from the stream), and extensively forested (woody vegetation >50m wide from the stream). There was a significant difference in the floristic quality and percent native species between riparian zones with deforested, moderately forested, and extensively forested riparian zones ($P<0.001$). Extensively forested riparian zones possess a higher average percent native species ($P<0.001$) and average adjusted floristic quality assessment index (FQAI') score ($P<0.05$) than the other two treatments. Based on these results, to protect native biodiversity, wider riparian forests should be considered when implementing land management strategies in riparian landscapes.

Introduction:

Riparian zones are an important and complex part of the ecosystem. Serving as a transitional zone between aquatic and terrestrial environments, they make up only a small fraction of the landscape. However, they are among the more productive and diverse land-based systems on the planet (Naiman, Décamps & Pollock 1993). Functions provided by riparian zones include temperature regulation for streams, removal of excess sediment and nutrients from runoff, bank stabilization, and corridor/habitat for animals. Riparian zones are also particularly important in the maintenance of regional biodiversity. These zones are hotspots for botanical biodiversity, and typically have higher species richness than adjacent upland areas (Decocq 2002; Gregory *et al.* 1991; Hughes & Spackman 1995; Naiman, Décamps & Pollock 1993). This high species richness is due to both the position of riparian zones on the landscape (as an ecotone) and the frequent natural disturbances they experience, which keep the system in a non-equilibrium state and prevent competitive exclusion. These factors combine to create unique edge habitat niches that are not found elsewhere and allow for a wide range of species to coexist. As such, riparian zones are able to support a diverse and unique flora that is distinct from surrounding areas (Gregory *et al.* 1991; Naiman, Décamps & Pollock 1993).

Threats to biodiversity in riparian zones:

Deforestation due to urbanization and agriculture is a major threat to biodiversity, especially in riparian systems. A large amount of forested riparian corridors in North America and Europe have been lost over the past two centuries (Naiman, Décamps & Pollock 1993) with a consequent reduction in biodiversity. This is not to say that other area have not also suffered form deforestation, but due to riparian zones functions in protecting aquatic resources, proving habitat for wildlife and being biodiversity hotspots they are of special concern.

Not only are riparian zones being rapidly deforested, they are also extremely vulnerable to establishment of non-native species than surrounding areas. Hood & Naiman 2000; Stohlgren *et al.* 1998; Stohlgren *et al.* 2002 have shown that riparian zones can harbor high native species richness as well as a significantly higher numbers of non-native species. It was once held as an ecological paradigm that areas with high biodiversity were protected from establishment of non-native species through the process of competitive exclusion and resource allocation (Elton 1958; Tilman 1999). However, more recent evidence suggests that the opposite is true and that these areas are highly susceptible to invasion (Davis, Grime & Thompson 2000; Kumar, Stohlgren & Chong 2006; Planty-Tabacchi *et al.* 1996; Stohlgren *et al.* 2002; Stohlgren, Barnett & Kartesz 2003). Factors that help to sustain high levels of native biodiversity, such as disturbance regime and resource availability, also help to sustain high levels of non-native species (Davis, Grime & Thompson 2000; Richardson *et al.* 2007; Stark, Bunker & Carson 2006; Stohlgren *et al.* 2002; Stohlgren, Barnett & Kartesz 2003). Additionally, increased edge effect caused by deforestation opens riparian communities to invaders (Kumar, Stohlgren & Chong 2006), which makes it easier for invasive species to gain access to the riparian community. Streams can facilitate spread of certain plants throughout the drainage network and cause riparian zones to act as corridors for invasion (Johansson, Nilsson & Nilsson 1996). Given such biological importance and vulnerability, riparian zones should not be ignored or viewed as able to fend for themselves against invaders.

Disagreement about minimum width for proper biological function and competition for land use have led to conflicts related to land use practices and riparian zones. There are some guidelines about the minimum width of a properly functioning riparian zone, but these are highly variable depending on which function you are concerned about maintaining (Castelle, Johnson & Conolly 1994; Hawes & Smith 2005; Hughes & Spackman 1995). The purpose of this study is to assess if there is a relationship between the forested width of a riparian zone and the floristic quality of the plant community. Previous studies investigating riparian zone size have focused individually on environmental condition (Ives *et al.*), invasive species (Ferris, D'Amico & Williams 2012), conservation of biodiversity (Barton, Taylor & Biette 1985; Hughes & Spackman 1995), or have examined how wildlife respond to riparian corridors of varying sizes (Hughes & Spackman 1995; Marczak *et al.* 2010). In this study, by incorporating a plant community-based bioassessment tool to assess habitat quality I determined wider riparian zones provide more protection from the impacts of anthropogenic disturbance and provide higher quality habitats for plants, including limiting invasion by nonnative species.

Objectives:

1. Examine how floristic quality and plant community composition are affected by forested riparian zone width.

2. Determine the role that forested riparian zone size plays in limiting invasion by non-native species into riparian communities.

3. Determine if wider riparian zones provide more protection from the effects of anthropogenic disturbance, determined by comparing floristic quality between treatment groups.

Methods:

Study Area

Shenandoah County is located in the Ridge and Valley province of Virginia. This region is characterized by a series of parallel ridges and valleys that create considerable environmental heterogeneity. Shenandoah County encompasses 512 square miles. The area is largely rural, with 39% of the county dedicated to agriculture (Comprehensive Plan Citizens Advisory Committee 2014). Farming is primarily restricted to the valley bottom. The county is bordered on both the East and West side by the George Washington – Jefferson National Forest, which covers almost 25% of the county. Forested areas are characterized by upland oak-hickory forests and valley woodlands, but the environmental heterogeneity of the county creates a wide variety of habitats that support unique plant communities. Shenandoah County represents 49% of the total North Fork watershed, and 7% of the total Potomac River watershed. The North Fork of the Shenandoah River runs through the county and is fed by nearly 1150 miles of permanent and intermittent streams (Comprehensive Plan Citizens Advisory Committee 2014).

Experimental design

Six low order streams in Shenandoah County, Virginia, were sampled between May and August of 2013 and June 2014. Streams were randomly chosen from a list of streams that met the minimum requirements as listed below.

Shenandoah County, Virginia

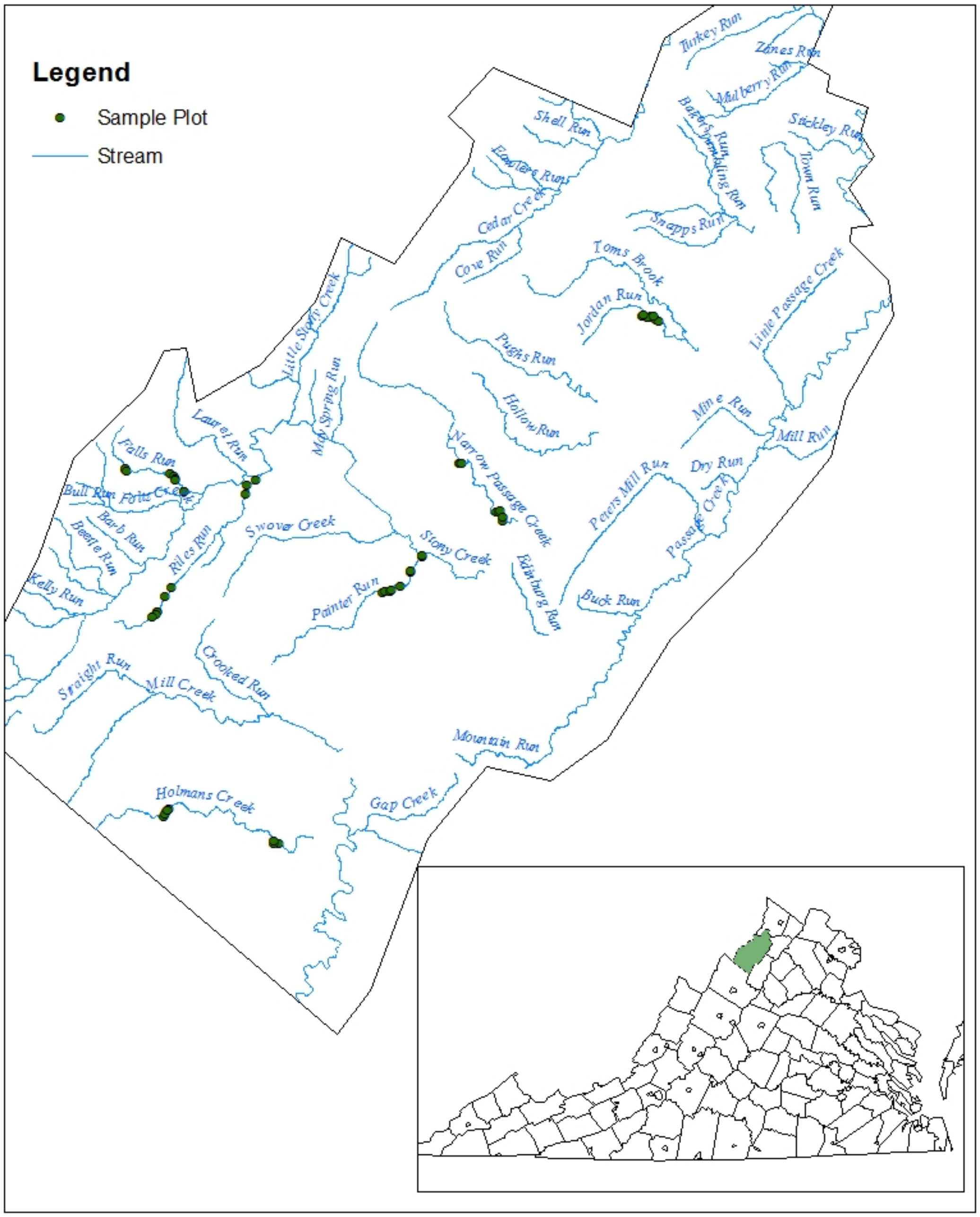

Figure 1. Map of Shenandoah County, Virginia study area. Location of sample plots (n=53), and streams in study area. Inset map shows location of Shenandoah County in Virginia. Map created in Arc GIS 10.1.

- Minimum of five miles long - to increase likelihood of capturing an adequate number of different forest widths
- First or second order - to avoid inherent differences in vegetation of low and high order streams
- Perennial/permanently flowing

Three treatment groups were assigned to keep equal representation among different riparian forest conditions. The riparian zones were defined as being deforested, moderately forested, or extensively forested. Deforested riparian zones were defined as areas having a single line of trees or less bordering the stream. These sites represent pastures and meadows that are defined as disturbed communities that are irregularly maintained or used for cattle grazing or hay feed, and are dominated by graminoides and composites (Poindexter 2013). Moderately forested areas were defined as areas with more than a single line of trees perpendicular the stream up to 50 meters. Extensively forested areas were defined as having more than 50 meters of forested area perpendicular the stream. These width designations were modified from the anthropogenic activity index (AAI) (Ervin *et al.* 2006). Forest width measurements were made from the stream edge to the forest edge. Widths were determined using satellite imagery and then checked in the field. It should be noted that although the entire forest width from the stream to the forest edge was measured for treatment assignment, only the vegetation immediately adjacent to the stream was sampled.

Due to the difficulties associated with surveying privately owned land, an incomplete randomized block design was used for this survey. Property lines used as a blocking factor and sampling was randomized within the blocks. Properties were chosen by the investigator were dependent on the presence of a long stream segment (>200m) and owner's consent. Treatment groups were assigned based on the forest width. This was repeated until each treatment group was represented three times on a stream. This was an incomplete block design, as each treatment was not necessarily represented in each block and might be represented multiple times per block.

Plot measurements

A nested plot design was used for vegetation sampling. Plots were 20x20 meters, with each divided into three sections for sampling (Figure 2). Herbaceous vegetation was sampled for a 5x20 meter area perpendicular to the stream. Shrubs and woody vines were sampled for a 10x20 meter area perpendicular to the stream. Trees were sampled for the entire 20x20 meter sample area. Plant habits were defined following *Vegetation Classification Guidelines* as set by the National Parks Service (Lea 2011). A random number generator was used for plot placement within blocks, with plots a minimum of 50 meters apart. To avoid bias, the corner of each plot was placed at the randomly chosen coordinate and the plot was measured in the direction of stream flow unless there was an obstruction or a sharp bend in the stream that prevented this, in which case it was measured in the opposite direction. In each plot a species inventory was taken and an effort was made to collect voucher specimens for each species at least once during the study. Abundance data was not taken, as it can fluctuate greatly throughout the years or depending on season, and is therefore not relevant when measuring the qualitative value of a site when using the floristic quality assessment index (Wilhelm & Masters 1995). Species that were difficult taxonomically were taken back to the lab

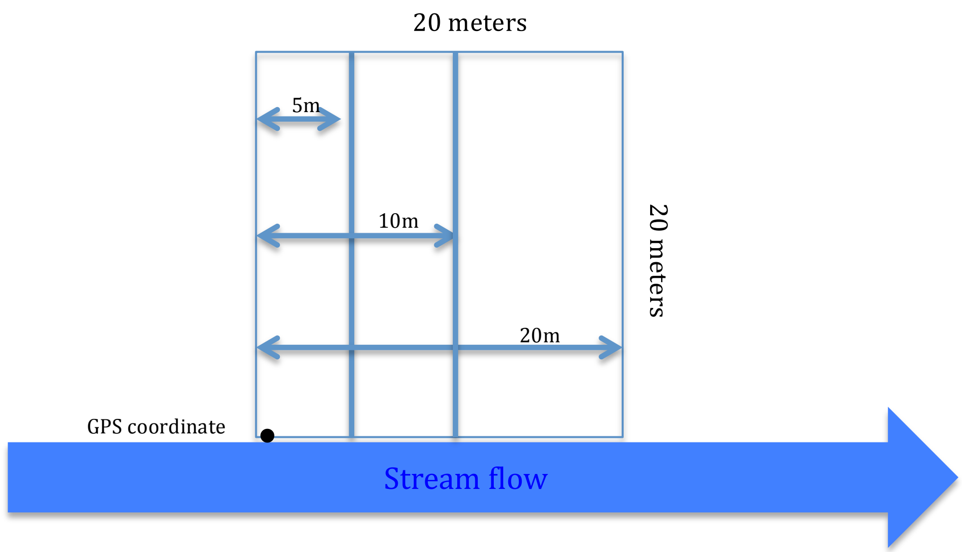

Figure 2. Plot design for nested vegetation sampling. Species composition for each plot was recorded with herbaceous vegetation sampled in a 5x20 meter section, shrubs and woody vines in a 10x20 meter section, and trees in the entire 20x20 meter plot. 53 vegetation plots were sampled during this study, 18 for each treatment group across six streams in Shenandoah County.

to be identified. Identifications for herbarium voucher specimens follow Weakley, Ludwig and Townsend (2012), however all species used in analysis and listed in Appendix 1 follow the USDA PLANTS database (USDA 2010) as the nomenclatural authority because that is the authority used by the Mid-Atlantic floristic quality assessment index. Voucher specimens are housed in the James Madison University herbarium (JMUH).

Floristic quality score assignment

The bioassessment tool used to evaluate the habitat quality of each plot was the Floristic Quality Assessment Index (FQAI). Originally created in Ohio (Swink & Wilhelm 1979), it has now been adopted by several states and regions across the country. This method is gaining popularity with natural resource managers due to the fact the herbaceous plants, unlike woody species, are able to respond quickly to changes (improvements and degradations) in habitat quality (Ervin *et al.* 2006). Native species receive a score from 0-10, based on that species habitat range and its tolerance to disturbance; non-native species are not assigned a score (Chamberlain & Ingram 2012). These scores represent the coefficient of conservation (C) and they are assigned to each species by a panel of experts (Chamberlain & Ingram 2012). This study utilizes the Ridge and Valley province section of the Mid-Atlantic floristic quality assessment index. Species lists for each plot were entered into the Mid-Atlantic Floristic Quality Assessment Index (Mid-Atlantic Wetland Work Group 2013) to obtain C scores for each species. These scores were used to calculate several measures including:

Floristic quality Index (FQAI)

$$FQAI = \overline{C} \times \sqrt{N} \qquad \text{(Chamberlain \& Ingram 2012)}$$

- Where N is the number of native species and $\overline{C}$ is the mean conservation coefficient

Adjusted Floristic quality (FQAI')

$$FQAI' = \left(\frac{\overline{C} \times \sqrt{N}}{10 \times \sqrt{N+A}}\right) \times 100$$ (Chamberlain & Ingram 2012)

- Where N is the number of Native species and A is the number of non-native species.

FQAI' is adjusted to account for the influence of non-native species, which are not assigned a C score, and therefore not treated in the original FQAI measure, and to reduce the influence of species richness on the index score (Miller & Wardrop 2006). Because the influence of non-native species is an important factor in this study, FQAI' is presented in the analysis as the primary measure of floristic quality.

This plant community-based assessment of habitat quality has been extensively studied, and has been shown to give consistent and reliable results when assessing the impact of anthropogenic disturbance in wetlands (Bried, Jog & Matthews 2013; Chamberlain & Ingram 2012; Ervin *et al.* 2006; Lopez & Fennessy 2002; Miller & Wardrop 2006).

Statistical Analysis

Differences in plant community composition among treatment groups were detected using principle coordinate analysis (PCO) and PERMANOVA. Plant species data were recorded as presence or absence data (0 or 1) and were used to create a Sorensen's resemblance matrix with preimer-e multivariate statistical software for ecologists (Clarke, KR, Gorley, RN 2006). PCO was used because the data I were using was binary. Because of the non-normal nature of binary data the resemblance matrix was obtained via permutation of the data to find the best distribution. Permutational MANOVA (PERMANOVA) was used to detect significant differences between species composition of several factors including treatment groups and location (mountain vs valley). PERMANOVA used a mixed model design with treatment category and location as fixed factors and stream as a random factor nested inside location.

Differences in FQAI, FQAI', and percent non-native species were detected using a mixed generalized linear model ANOVA (IBM Corp. 2013). In this model, treatment group and location (mountain or valley) were used as fixed effects. Location was added into the model after examination of principal coordinate analysis (PCO) results showed that there was a distinct species compositional difference between mountain and valley riparian communities. The model treated streams as a random source of variation because they were a subset chosen from a larger sample pool. This random factor was then nested inside location (valley streams or mountain streams). Because stream had no significant interaction in the model it is not discussed in the results.

When ANOVA's were significant, post hoc tests were performed using pairwise contrasts with a Bonferroni correction, which gives a more conservative p-value and corrects for multiple comparisons. Normality assumptions were violated by FQAI' and percent non-native species data and were therefore transformed using a square root transformation.

Results:

In this study, 243 species of vascular plants representing 81 families were recorded and used for analysis for the six streams sampled in Shenandoah County between May and August of 2013 and June of 2014 (see Appendix 1 for full species list). Of the 243 species, 65% were native, meaning they are thought to have been present in the area prior to 1600's (Andreas & Lichvar 1995). Obligate wetland and facultative wetland species comprised 0.04% and 0.1% of the total species, respectively (Appendix 1).

Floristic quality indices (FQAI) above 35 have high enough quality in richness and conservatism to be considered "floristically important" areas, whereas FQAI below 20 represent areas where the natural quality is of minimum significance (Wilhelm & Masters 1995). Overall, the floristic quality of the riparian zones in this study was low. Only 10 of the sites studied (6 extensively forested sites and 4 moderately forested) had FQAI over 20, and none were above 35.

Trends in FQAI and treatment groups show that there is a relationship between forested width and floristic quality (Table 1). Treatment had a significant effect on all measures assessed in the model (Table 1; $P < 0.001$). The average FQAI for extensively forested sites was more than double the average for deforested sites, 18.6 and 9.05 respectively (Appendix 2). The post hoc pairwise comparison with a Bonferroni correction reveals that there is a significant difference in the FQAI between deforested sites and forested sites, both extensively and moderately forested, ($P < 0.001$). No significant difference was detected between moderately forested and deforested sites ($P = 0.064$). All treatment groups were significant for FQAI' ($P < 0.05$) (Figure 3).

The percent of native species present in a plot increased when moving from deforested areas to extensively forested areas (ANOVA, $P < 0.001$) (Table 1, Figure 4). Eighty percent of the 85 non-native species recorded in this study were present in deforested treatment plots. Of that 80%, more than half (37) were recorded only in deforested treatments, and were not present in moderately or extensively forested treatments (Appendix 3). The more common non-native species encountered were *Ailanthus altissima*, *Alliaria petiolata*, *Berberis thunbergii*, *Elaeagnus umbellate*, *Glechoma hederacea*, *Hesperis matronalis*, *Ligustrum sinense*, *Lonicera japonica*, *Microstegium vimineum*, *Rosa multiflora*, and *Rubus phoenicolasius*. Eight of these ten species are considered highly invasive by the Virginia department of Conservation and Recreation (Heffernan *et al.* 2001). Percent native species in a plot exhibits a strong positive correlation with FQAI' ($R^2 = 0.992$; $P < 0.001$) (Figure 5). A similar trend was exhibited between percent native species and FQAI, but less strongly correlated ($R^2 = 0.64$; $P < 0.001$).

Principal coordinate analysis (PCO) of species composition data (Figure 6) reveals a significant change in plant species community composition between treatment groups (PERMANOVA $P < 0.001$). Axis PCO 1 is able to explain 14.4% of the variation seen in the species compositions of the plots. PCO1 seems to be corresponding to the treatment groups, clustering forested sites (moderate and extensive) and deforested sites (Figure 6). Post hoc pairwise comparisons reveal a significant difference in species compositions between deforested sites and both types of forested sites (moderately forested $t = 2.01$ $P<0.001$; extensively forested $t= 2.08$, $P<0.001$), but no significant compositional differences between moderately and extensively forested sites ($t = 0.164$,

	Floristic Quality Index (FQAI)		Adjusted Floristic Quality Index (FQAI')		Percent Native Species	
	F	P	F	P	F	P
Fixed effects						
Treatment	**28.966**	**0.000**	**38.967**	**0.000**	**30.839**	**0.000**
Location	0.540	0.467	3.059	0.089	**4.346**	**0.044**
Treatment*Location	1.039	0.364	**3.286**	**0.049**	1.225	0.297

P>0.05). There is also a species compositional shift between mountain and valley sites (P < 0.001) (Figure 7), most likely corresponding to axis PCO 2 (11.9%).

Table 1. Mixed generalized linear model ANOVA results for the effect of treatment and location on Floristic Quality Indices, Adjusted Floristic Quality Indices, and percent native species. Treatment was highly significant for all measures (P <0.001). Stream was also included in the model as a random factor but showed no significant interaction with treatment.

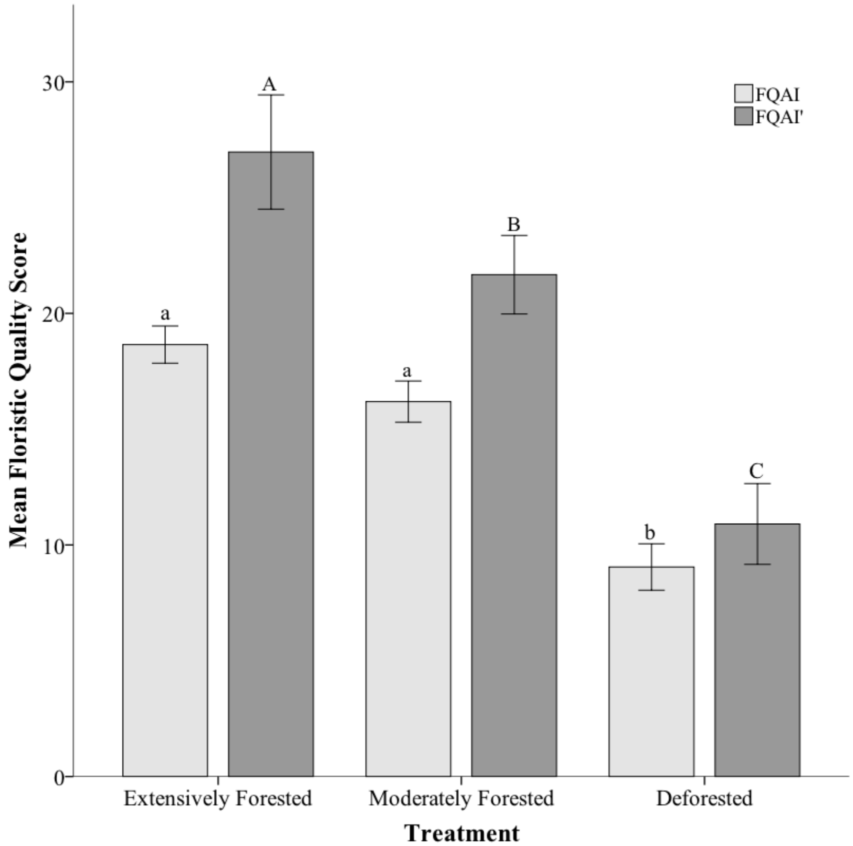

Figure 3. Effect of treatment group on mean Floristic Quality Index (FQAI) and Adjusted Floristic Quality Index (FQAI') (+/- 1 SE). Treatments with different letters are significantly different from one another (Pairwise contrasts with Bonferroni correction; $P < 0.05$). Lower case letters on error bars represent FQAI and capital letters represent FQAI'.

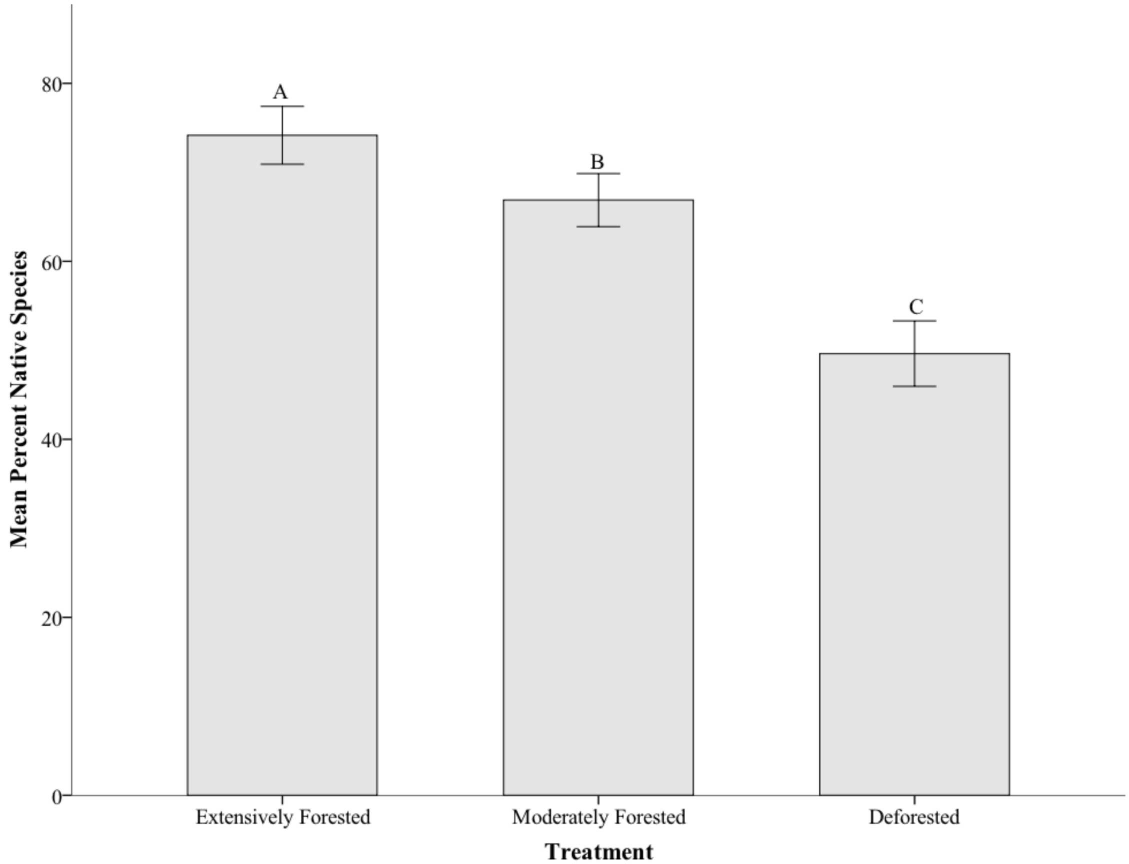

Figure 4. Effect of treatment on the average percent of native species recorded for a 20x20m nested plot. All treatment groups are significant (Pairwise contrasts with Bonferroni correction; $P < 0.05$).

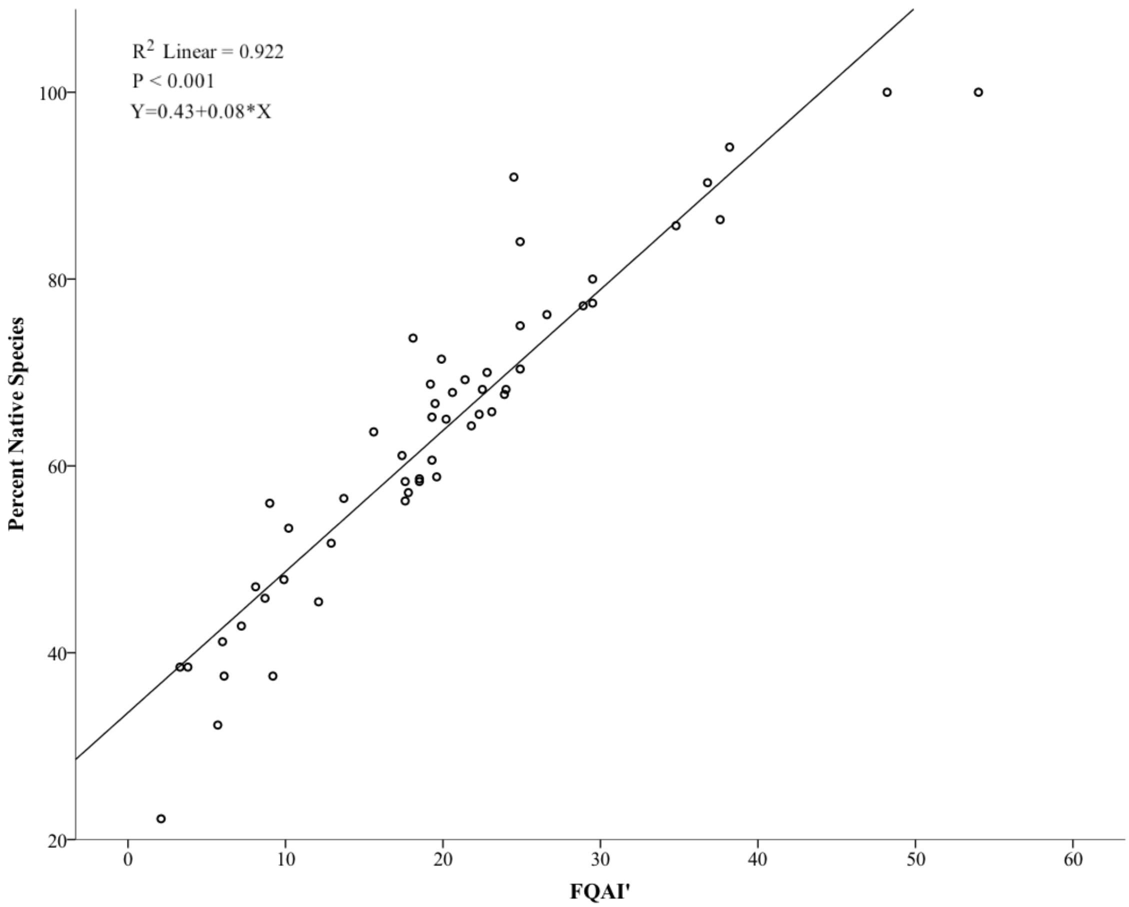

Figure 5. Percentage of native species in a plot was highly correlated with FQAI’ ($R^2 = 0.922$; $P < 0.001$). This suggests that percent native species may also be a good indicator of disturbance in riparian zones. Log transformation removed for graph.

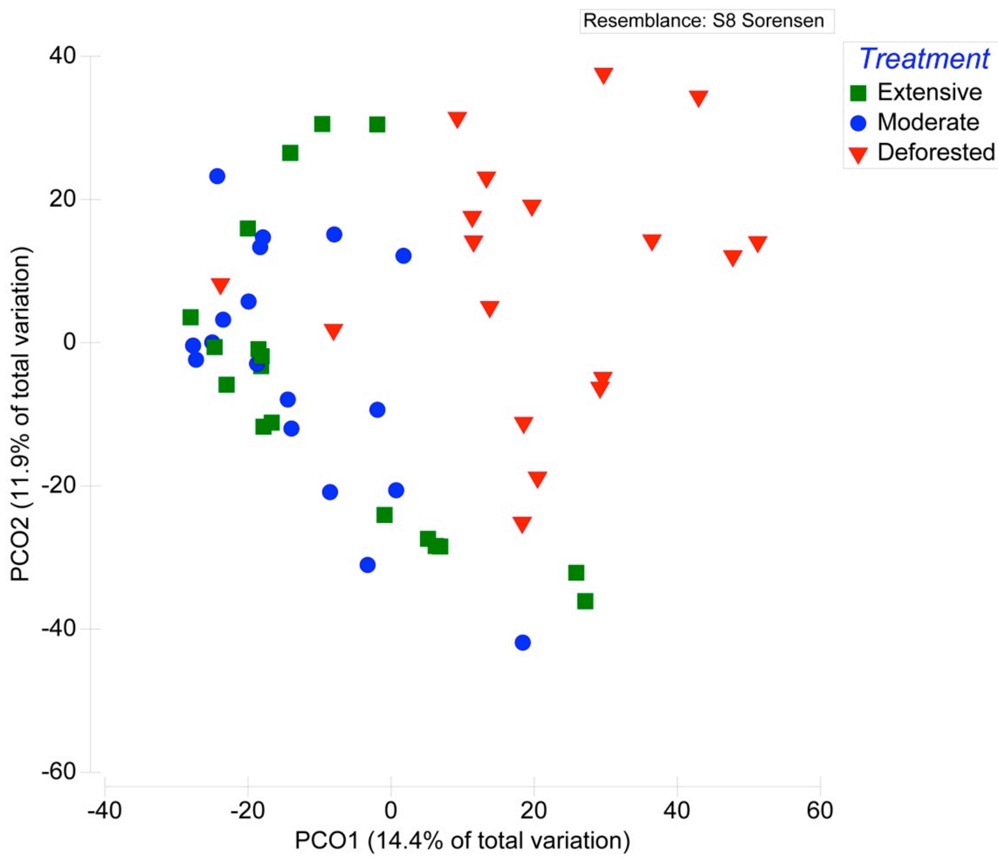

Figure 6. Principal Coordinate (PCO) Analysis showing the effect of treatment on species composition. The species composition in deforested treatment groups is significantly different from the species composition of moderately forested and extensively forested groups (PERMANOVA pairwise comparison, $P < 0.001$). Each point on the graph represents sample a plot (n=18 per treatment group).

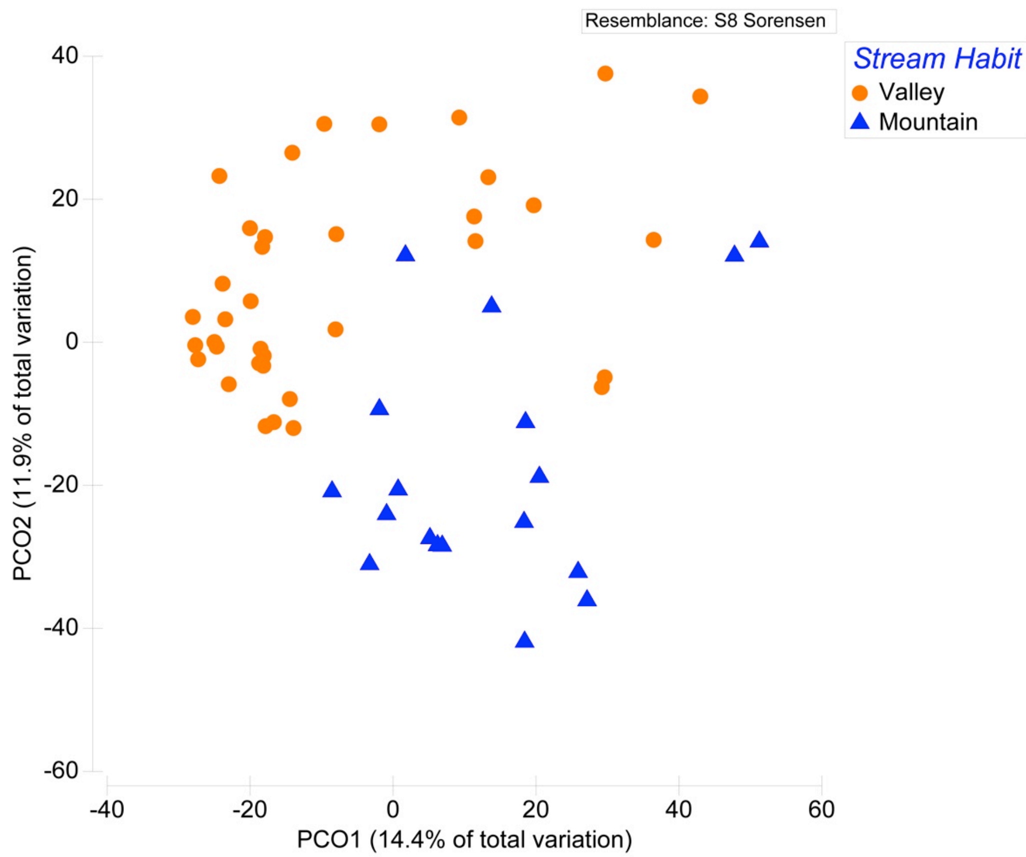

Figure 7. Principal Coordinate (PCO) Analysis showing the effect of location on species composition for each plot (n=53). The species composition is significantly different for mountain and valley plots (PERMANOVA, P < 0.001). Each point represents a sample plot (n=18 for mountain plots and n=36 for valley plots).

Discussion:

The floristic quality assessment index (FQAI) is negatively correlated with anthropogenic disturbance in stream bank and wetland communities (Bowers & Boutin 2008; Lopez & Fennessy 2002; Miller & Wardrop 2006). As the disturbance in an area increases, the plant community exhibits a decrease in floristic quality. This disturbance may come from a variety of sources: hydrological alterations, changes in adjacent land use, buffer condition, amount of forested area. In this study, floristic quality assessment was used to determine if the wider forested riparian zones provide more protection from disturbance and limit invasion from non-native species, resulting in overall higher floristic quality in areas with wider riparian forests.

It has been demonstrated that plant community composition changes in response to a disturbance gradient (Bowers & Boutin 2008; Malik, Shinwari & Waheed 2012). Principal coordinate analysis (PCO) PERMANOVA shows that the species that make up plant communities for deforested treatment plots are significantly different the species composition of plant communities in moderately or extensively forested treatment plots. The low percentage of variation that the axes were able to explain could partly be due to the high number of species used in the analysis (243) and the low number of replicates per treatment (n=18), especially when considering that a large percentage of species were only found in one plot. A disadvantage to using PCO over other types of ordination methods is that there is no way to determine what the axes represent, which limits the conclusions that can be drawn. However, a significant species composition difference was determined based on both treatment group and location.

Overall, the FQAI scores recorded for riparian zones in Shenandoah County seemed low. The standard set by Wilhelm and Masters (1995) for identifying an area as having great enough floristic quality to be considered to have natural area potential (worthy of conservation) is a FQAI of 35, with areas scoring below 20 considered to be of little significance for conservation. In this study, no site had a score that was over 35. This could possibly be due to the disturbance history of the area from sources such as clear-cutting during national expansion and the large amount of agriculture practiced in the Shenandoah Valley (Weakley, Ludwig & Townsend 2012). However, because the FQAI is highly affected by area (Matthews *et al.* 2005), the low scores could be due to the fact that a relatively small plot size (nested 20x20m) was used in this study. Because FQAI has a tendency to increase with area there is a bias towards higher floristic quality in larger sample areas (Matthews *et al.* 2005). Wilhelm and Masters (1995) do not specify the appropriate sampling area size to determine if the area is of significant conservation value, only that a "relevant" portion should be sampled as completely as possible. Because there is not a standard sampling size for FQAI studies, it is difficult to compare these results directly with FQAI site scores from other studies, and therefore hard to make generalized statements about the overall floristic quality of riparian zones in this study.

The importance of riparian forests in protecting regional biodiversity and floristic quality has been well documented (Bowers & Boutin 2008; Hughes & Spackman 1995; Ives *et al.* ; Kumar, Stohlgren & Chong 2006; Miller & Wardrop 2006). In regards to biodiversity, Hughes and Spackman (1995) found that in naturally forested riparian areas (of at least 200 m x 200m) a distance of 10 to 30 meters was necessary to capture >90%

of vascular plant biodiversity present, but this number was highly variable by stream. Bowers and Boutin (2008) found that both FQAI and percent native species were highly correlated with a disturbance gradient, increasing as you move from open pasture to naturally forested habitats ($P < 0.001$). Similarly, in this study FQAI, FQAI', and percent native species all increased significantly as forested riparian width increased ($P < 0.001$).

Widely forested riparian zones may also help exclude non-native species. Ferris et al. (2012) determined that some non-native species (*Alliaria petiolata* and *Celastrus orbicularis)* show a decline in wider forested areas and are less able to penetrate into the forest interior. Although, in this study *Alliaria petiolata* was present in 7 of 18 of the extensively forested plots. Further investigation would be needed to determine if this species exhibits the same patterns of decline in large riparian forests reported by Ferris et al. (2012) in Shenandoah County. Despite several highly invasive species being common in this study, there was an overall decline in the presence of non-native species in wider forested riparian zones. It is important to note that not all non-native species are have a large negative impact on native plant communities, the ones that do are termed invasive. Highly invasive species are very strong competitors that can changes in species abundance, lower biodiversity, and change productivity of a site (Heffernan *et al.* 2001; Zedler & Kercher 2004).

Surrounding land use can also affect floristic quality. Lopez and Fennessy (2002) reported that FQAI was lower in areas surrounded by agricultural lands. This could partially explain the interaction between treatment and location seen in this present study, due to agriculture being primarily restricted to valley bottoms in the Ridge and Valley province (Chamberlain & Ingram 2012). However, more investigation would be needed to test this as that was not the main objective of the present study.

Although there was a positive correlation between percent native species and FQAI (R2 0.64, P < 0.001), a stronger correlation was reported between percent native species and FQAI'. This concurs with findings from Ervin et al. (2006), which found a correlation with non-native species richness and FQAI, but also found that when non-native species information was added to the index (modified as FAQWet4) there was an even stronger correlation. Similarly, it has been demonstrated that a negative correlation exists between non-native species richness and FQAI' ($R^2 = 0.058$, $P < 0.001$) (Miller & Wardrop 2006). This present study has shown that as the percent native species increases, FQAI' also increases. Because non-native species have the potential to stress the system (Catford *et al.* 2012; Hobbs & Huenneke 1992) it is a more realistic and accurate measure of site quality to include non-native species in the assessment (Miller & Wardrop 2006). Although FQAI' more clearly showed the differences in treatment groups, this correlation also suggests that percent native species may also give a reasonable estimate of site disturbance.

Conclusions

This study demonstrates that there is a significant positive relationship between the width of a riparian zone, the percentage of native species, and the floristic quality in that area. From this study it can be concluded that, based on floristic quality, areas with wider riparian forests harbor a greater percentage of native species and based on floristic quality are more conserved. Therefore, maintaining wider riparian zones may protect natural riparian plant communities for anthropogenic disturbance. Wider riparian zones also exclude some non-native species. Mechanisms for non-native species exclusion may be through creating unfavorable conditions for some non-native species, such as low light in densely forested areas. When implementing land management practices, wider forest buffers should be conserved in order to protect the native biodiversity of riparian zones in Shenandoah County, Virginia. Protecting native biodiversity in riparian zones is important because specialist species may be more susceptible to extinction from habitat loss and invasion. Future research examining the abundance of non-native and invasive species in relation to forest width is recommended to understand the extent of invasion in riparian zones and to determine if invasive species pose a greater threat in deforested areas.

Appendix 1

Species list with: family, species name, nativity status, Coefficient of conservation score (C), and wetland indicator status. Nomenclature follows USDA PLANTS database (USDA 2010)and C scores and wetland codes are from Penn State Floristic Quality Assessment calculator (Mid-Atlantic Wetland Work Group 2013)

	Family	Species	Native	C	Wetland status
Pteridophytes	Aspleniaceae	*Asplenium platyneuron* (L.) Britton, Sterns & Poggenb.	Y	3	FACU
	Dennstaedtiaceae	*Dennstaedtia punctilobula* (Michx.) T. Moore	Y	2	FACU
		Dryopteris intermedia (Muhl. ex Willd.) A. Gray	Y	5	FACU
	Dryopteridaceae	*Polystichum acrostichoides* (Michx.) Schott	Y	5	FACU
	Equisetaceae	*Equisetum arvense* L.	Y	1	FAC
		Equisetum hyemale L. var. *affine* (Engelm.) A.A. Eaton	Y	2	FACW
	Pteridaceae	*Adiantum pedatum* L.	Y	7	FAC
	Thelypteridaceae	*Thelypteris noveboracensis* (L.) Nieuwl.	Y	5	FAC
Gymnosperm	Cupressaceae	*Juniperus virginiana* L.	Y	3	FACU
	Pinaceae	*Pinus echinata* Mill.	Y	8	
		Pinus strobus L.	Y	6	FACU
		Pinus virginiana Mill.	Y	5	
Monocots	Amaryllidaceae	*Allium canadense* L.	Y	3	FACU
		Allium vineale L.	N		FACU
	Araceae	*Symplocarpus foetidus* (L.) Salisb. ex W.P.C. Barton	Y	5	OBL
	Cyperaceae	*Carex blanda* Dewey	Y	3	FAC
		Carex frankii Kunth	Y	4	OBL
		Carex hirsutella Mack.	Y	4	
		Carex muehlenbergii Schkuhr ex Willd.	Y	6	
		Carex rosea Schkuhr ex Willd.	Y	5	FACU
		Carex scoparia Schkuhr ex Willd.	Y	4	FACW
		Carex stipata Muhl. ex Willd.	Y	3	OBL
		Carex swanii (Fernald) Mack.	Y	4	FACU
		Scirpus atrovirens Willd.	Y	3	OBL
	Juncaceae	*Juncus dichotomus* Elliott	Y	4	FACW
		Juncus effusus L.	Y	2	FACW
	Liliaceae	*Asparagus officinalis* L.	N		FACU
		Hemerocallis fulva (L.) L.	N		FACU
		Hypoxis hirsuta (L.) Coville	Y	7	FAC
		Maianthemum racemosum (L.) Link	Y	5	FACU
		Medeola virginiana L.	Y	7	
		Ornithogalum umbellatum L.	N		FACU
	Poaceae	*Agrostis gigantea* Roth	N		FACW
		Bromus arvensis L.	N		FACU
		Bromus sterilis L.	N		
		Cynodon dactylon (L.) Pers.	N		FACU
		Dactylis glomerata L.	N		FACU

		Danthonia compressa Austin	Y	4	FACU
		Dichanthelium clandestinum (L.) Gould	Y	2	FAC
		Dichanthelium dichotomum (L.) Gould	Y	4	FAC
		Digitaria ciliaris (Retz.) Koeler	N		FACU
		Eleusine indica (L.) Gaertn.	N		FACU
		Elymus hystrix L. var. hystrix	Y	5	UPL
		Elymus repens (L.) Gould	N		FACU
		Elymus riparius Wieg.	Y	5	FACW
		Elymus villosus Muhl. ex Willd.	Y	4	FACU
		Elymus virginicus L. var. *virginicus*	Y	4	FACW
		Festuca subverticillata (Pers.) Alexeev	Y	6	FACU
		Glyceria striata (Lam.) Hitchc.	Y	5	OBL
		Holcus lanatus L.	N		FAC
		Microstegium vimineum (Trin.) A. Camus	N		FAC
		Phalaris arundinacea L.	Y	0	FACW
		Phleum pratense L.	N		FACU
		Poa pratensis L.	N		FACU
		Poa trivialis L.	N		FACW
		Schedonorus arundinaceus (Schreb.) Dumort., nom. cons.	N		
		Sorghum halepense (L.) Pers.	N		FACU
		Tridens flavus (L.) Hitchc.	Y	1	FACU
		Tripsacum dactyloides (L.) L.	Y	4	FACW
	Polygonaceae	*Polygonum hydropiper* L.	N		
		Polygonum hydropiperoides Michx.	Y	4	
Dicots	Aceraceae	*Acer negundo* L.	Y	2	FAC
		Acer pensylvanicum L.	Y	5	FACU
		Acer platanoides L.	N		UPL
		Acer rubrum L.	Y	1	FAC
		Acer saccharum Marshall	Y	6	FACU
	Amaranthaceae	*Amaranthus spinosus* L.	N		FACU
	Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	Y	1	FAC
	Annonaceae	*Asimina triloba* (L.) Dunal	Y	5	FAC
	Apiaceae	*Angelica triquinata* Michx.	Y	7	
		Conium maculatum L.	N		FACW
		Cryptotaenia canadensis (L.) DC.	Y	4	FAC
		Daucus carota L.	N		UPL
		Osmorhiza longistylis (Torr.) DC.	Y	5	FACU
		Sanicula canadensis L.	Y	3	UPL
		Torilis japonica (Houtt.) DC.	N		
	Apocynaceae	*Vinca minor* L.	N		

Araliaceae	*Hedera helix* L.	N		
Aristolochiaceae	*Asarum canadense* L.	Y	7	FACU
Asclepiadaceae	*Asclepias syriaca* L.	Y	1	FACU
Asteraceae	*Achillea millefolium* L.	Y	0	FACU
	Ambrosia artemisiifolia L.	Y	1	FACU
	Arctium minus Bernh.	N		FACU
	Cichorium intybus L.	N		FACU
	Cirsium vulgare (Savi) Ten.	N		FACU
	Erigeron annuus (L.) Pers.	Y	0	FACU
	Erigeron philadelphicus L.	Y	1	FACU
	Erigeron strigosus Muhl. ex Willd.	Y	1	FACU
	Eutrochium purpureum (L.) E.E. Lamont	Y	5	
	Galinsoga quadriradiata Cav.	N		FACU
	Helianthus decapetalus L.	Y	5	FACU
	Heliopsis helianthoides (L.) Sweet	Y	5	FACU
	Lactuca serriola L.	N		FAC
	Leucanthemum vulgare Lam.	N		UPL
	Rudbeckia hirta L.	Y	2	FACU
	Solidago canadensis L.	Y	2	FACU
	Taraxacum officinale F.H. Wigg.	N		FACU
	Tussilago farfara L.	N		FACU
	Vernonia noveboracensis (L.) Michx.	Y	3	FACW
Balsaminaceae	*Impatiens pallida* Nutt.	Y	4	FACW
Berberidaceae	*Berberis thunbergii* DC.	N		FACU
	Podophyllum peltatum L.	Y	5	FACU
Betulaceae	*Alnus serrulata* (Aiton) Willd.	Y	5	OBL
	Betula lenta L.	Y	5	FACU
	Carpinus caroliniana Walter	Y	6	FAC
Bignoniaceae	*Catalpa speciosa* (Warder) Warder ex Engelm.	N		FAC
Brassicaceae	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	N		FACU
	Arabis canadensis L.	Y	6	
	Cardamine hirsuta L.	N		FACU
	Cardamine pensylvanica Muhl. ex Willd.	Y	6	OBL
	Hesperis matronalis L.	N		FACU
	Nasturtium officinale W.T. Aiton	N		OBL
	Sisymbrium officinale (L.) Scop.	N		
Cannabaceae	*Humulus japonicus* Siebold & Zucc.	N		FACU
Caprifoliaceae	*Lonicera japonica* Thunb.	N		FACU
	Lonicera morrowii A. Gray	N		FAC
	Lonicera tatarica L.	N		FACU

	Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli	Y	3	FAC
	Symphoricarpos orbiculatus Moench	Y	1	FACU
	Viburnum prunifolium L.	Y	5	FACU
Caryophyllaceae	*Cerastium brachypetalum* Pers.	N		
	Dianthus armeria L.	N		UPL
	Saponaria officinalis L.	N		FACU
	Silene vulgaris (Moench) Garcke	N		
Celastraceae	*Celastrus orbiculatus* Thunb.	N		FACU
Commelinaceae	*Commelina communis* L.	N		FAC
Convolvulaceae	*Calystegia sepium* (L.) R. Br.	Y	1	FAC
Cornaceae	*Cornus florida* L.	Y	4	FACU
	Nyssa sylvatica Marshall	Y	6	FAC
Cucurbitaceae	*Sicyos angulatus* L.	Y	3	FACU
Dioscoreaceae	Dioscorea polystachya Turczaninow	N		
	Dioscorea villosa L.	Y	5	FAC
Dipsacaceae	*Dipsacus fullonum* L.	N		FACU
Ebenaceae	*Diospyros virginiana* L.	Y	4	FAC
Elaeagnaceae	Elaeagnus umbellata Thunb.	N		
Ericaceae	*Kalmia latifolia* L.	Y	5	FACU
	Vaccinium stamineum L.	Y	6	FACU
Fabaceae	*Cercis canadensis* L.	Y	5	FACU
	Gleditsia triacanthos L.	Y	6	FAC
	Melilotus officinalis (L.) Lam.	N		FACU
	Robinia pseudoacacia L.	Y	1	FACU
	Securigera varia (L.) Lassen	N		
	Trifolium campestre Schreb.	N		
	Trifolium pratense L.	N		FACU
	Trifolium repens L.	N		FACU
Fagaceae	*Quercus alba* L.	Y	6	FACU
	Quercus montana Willd.	Y	7	
	Quercus rubra L.	Y	6	FACU
	Quercus velutina Lam.	Y	6	
Fumariaceae	Corydalis flavula (Raf.) DC.	Y	3	FACU
Hamamelidaceae	*Hamamelis virginiana* L.	Y	5	FACU
Hydrangeaceae	*Hydrangea arborescens* L.	Y	6	FACU
Iridaceae	*Sisyrinchium angustifolium* Mill.	Y	2	
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	Y	5	FACU
	Carya ovata (Mill.) K. Koch	Y	6	FACU
	Carya tomentosa (Lam.) Nutt.	Y	6	
	Juglans nigra L.	Y	4	FACU
Lamiaceae	*Clinopodium vulgare* L.	Y	1	

	Glechoma hederacea L.	N		FACU
	Lamium purpureum L.	N		
	Mentha spicata L.	N		FACW
	Monarda fistulosa L.	Y	5	UPL
	Nepeta cataria L.	N		FACU
	Scutellaria elliptica Muhl. ex Spreng.	Y	7	
	Teucrium canadense L.	Y	3	FACW
Lauraceae	*Lindera benzoin* (L.) Blume	Y	5	FAC
	Sassafras albidum (Nutt.) Nees	Y	3	FACU
Magnoliaceae	*Liriodendron tulipifera* L.	Y	5	FACU
Menispermaceae	*Menispermum canadense* L.	Y	5	FACU
Moraceae	*Broussonetia papyrifera* (L.) L'Hér. ex Vent.	N		UPL
	Maclura pomifera (Raf.) C.K. Schneid.	N		UPL
	Morus rubra L.	Y	6	FACU
Oleaceae	*Fraxinus americana* L.	Y	5	FACU
	Ligustrum sinense Lour.	N		FACU
Onagraceae	*Circaea lutetiana* L. ssp. *canadensis* (L.) Asch. & Magnus	Y	2	
Ophioglossaceae	*Botrychium virginianum* (L.) Sw.	Y	5	
Oxalidaceae	*Oxalis stricta* L.	Y	0	FACU
	Oxalis violacea L.	Y	6	
Papaveraceae	*Sanguinaria canadensis* L.	Y	5	UPL
Phytolaccaceae	*Phytolacca americana* L.	Y	1	FACU
Pinaceae	*Tsuga canadensis* (L.) Carrière	Y	8	FACU
Plantaginaceae	*Plantago major* L.	N		FACU
	Plantago virginica L.	Y	1	UPL
Platanaceae	*Platanus occidentalis* L.	Y	5	FACW
Polemoniaceae	*Phlox paniculata* L.	Y	4	FACU
Polygonaceae	*Polygonum amphibium* L.	Y	7	
	Polygonum cespitosum Blume var. *longisetum* (Bruijn) A.N. Steward	N		
	Polygonum erectum L.	Y	0	FACU
	Rumex crispus L.	N		FAC
	Rumex obtusifolius L.	N		FACU
	Claytonia virginica L.	Y	5	FAC
Pyrolaceae	*Chimaphila maculata* (L.) Pursh	Y	6	
Ranunculaceae	*Anemone virginiana* L.	Y	4	FACU
	Clematis virginiana L.	Y	3	FAC
	Hepatica nobilis Schreb. var. *obtusa* (Pursh) Steyerm.	Y	8	
	Ranunculus abortivus L.	Y	3	FACW
	Ranunculus bulbosus L.	N		UPL
	Ranunculus recurvatus Poir.	Y	4	FAC

	Thalictrum pubescens Pursh	Y	4	FACW
	Thalictrum thalictroides (L.) Eames & B. Boivin	Y	6	FACU
Rosaceae	*Duchesnea indica* (Andrews) Focke	N		
	Geum canadense Jacq.	Y	3	FACU
	Geum vernum (Raf.) Torr. & A. Gray	Y	1	FACU
	Prunus serotina Ehrh.	Y	3	FACU
	Rosa multiflora Thunb.	N		FACU
	Rubus allegheniensis Porter	Y	1	FACU
	Rubus flagellaris Willd.	Y	1	FACU
	Rubus occidentalis L.	Y	2	
	Rubus pensilvanicus Poir.	Y	2	FAC
	Rubus phoenicolasius Maxim.	N		
Rubiaceae	*Galium aparine* L.	Y	2	FACU
	Galium circaezans Michx.	Y	6	UPL
	Galium triflorum Michx.	Y	5	FACU
	Houstonia caerulea L.	Y	3	FACU
	Houstonia longifolia Gaertn.	Y	9	
	Mitchella repens L.	Y	6	FACU
Salicaceae	*Salix nigra* Marshall	Y	2	OBL
Scrophulariaceae	*Verbascum blattaria* L.	N		UPL
	Verbascum thapsus L.	N		FACU
	Veronica anagallis-aquatica L.	N		OBL
	Veronica hederifolia L.	N		
	Veronica serpyllifolia L.	N		FAC
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	N		FACU
Smilacaceae	*Smilax rotundifolia* L.	Y	2	FAC
	Smilax tamnoides L.	Y	5	
Solanaceae	*Physalis virginiana* Mill.	Y	1	
	Solanum dulcamara L.	N		FAC
Tiliaceae	*Tilia americana* L. var. *heterophylla* (Vent.) Loudon	Y	7	FACU
Ulmaceae	*Celtis occidentalis* L.	Y	4	FACU
	Ulmus pumila L.	N		FACU
	Ulmus rubra Muhl.	Y	4	FAC
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	Y	5	FACW
	Laportea canadensis (L.) Weddell	Y	5	FAC
	Parietaria pensylvanica Muhl. ex Willd.	Y	2	FACU
	Pilea pumila (L.) A. Gray	Y	4	FACW
	Urtica dioica L.	N		FACU
Verbenaceae	*Phryma leptostachya* L.	Y	5	FACU
Violaceae	*Viola sororia* Willd.	Y	3	FAC
	Viola striata Aiton	Y	4	FACW

Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Y	3	FACU
	Vitis cinerea (Engelm.) Engelm. ex Millard var. *baileyana* (Munson) Comeaux	Y	7	FACW
	Vitis labrusca L.	Y	4	FACU
	Vitis vulpina L.	Y	3	FAC

Wetland Category	**Symbol**	**Definition**
Upland	UPL	Occurs almost never in wetlands under natural conditions
Facultative Upland	FACU	Occasionally occurs in wetlands, but usually occur in non-wetlands
Facultative	FAC	Equally likely to occur in wetlands or non-wetlands
Facultative Wetland	FACW	Usually occur in wetlands, but occasionally found in non-wetlands
Obligate Wetland	OBL	Occurs almost always in wetlands under natural conditions

*Definitions of wetland indicator status taken from (Herman 2001)

Nativity status: Native = Y, Non-native = N

Appendix 2

Floristic quality data for low order streams in Shenandoah County, Virginia. Data collected between May 2013 to August 2013 and June 2014. Total mean C, native species richness, FQAI and FQAI' measures were all obtained from the floristic quality index calculator provided by Penn State (Mid-Atlantic Wetland Work Group 2013)Means and standard error were calculated for each treatment group.

Stream	Treatment	Location	Total Species Richness	Mean C	Native Species Richness	Percent Native Species	FQAI	FQAI'
Falls Run	Deforested	Mountain	25	1.2	14	56.0	8	9
Falls Run	Deforested	Mountain	23	1.4	11	47.8	9.9	9.9
Falls Run	Deforested	Mountain	16	1	6	37.5	6.5	6.1
Holman's Creek	Deforested	Valley	18	0.4	4	22.2	4	2.1
Holman's Creek	Deforested	Valley	17	1.2	8	47.1	7.1	8.1
Holman's Creek	Deforested	Valley	8	1.5	3	37.5	6.9	9.2
Jordan's Run	Deforested	Valley	24	2.9	18	75.0	16.3	24.9
Jordan's Run	Deforested	Valley	15	1.4	8	53.3	7.4	10.2
Jordan's Run	Deforested	Valley	13	0.5	5	38.5	3.1	3.3
Narrow Passage	Deforested	Valley	31	1	10	32.3	9.8	5.7
Narrow Passage	Deforested	Valley	28	1.1	12	42.9	8.9	7.2
Narrow Passage	Deforested	Valley	24	1.3	11	45.8	9.3	8.7
Painter Run	Deforested	Valley	28	2.7	18	64.3	17.9	21.8
Painter Run	Deforested	Valley	17	0.9	7	41.2	6	6
Painter Run	Deforested	Valley	13	0.6	5	38.5	3.6	3.8
Riles Run	Deforested	Mountain	22	2	14	63.6	11.5	15.6
Riles Run	Deforested	Mountain	21	3	16	76.2	16	26.6
Riles Run	Deforested	Mountain	19	2.1	14	73.7	10.7	18.1
Mean			*20.1*	*1.5*	*10.2*	*49.6*	*9.1*	*10.9*
S.E.			*1.4*	*0.2*	*1.1*	*3.7*	*1.0*	*1.7*
Falls Run	Moderate	Mountain	27	3	19	70.4	18.4	24.9
Falls Run	Moderate	Mountain	26	2.6	18	69.2	15	21.4
Falls Run	Moderate	Mountain	24	2.4	14	58.3	15.5	18.5
Holman's Creek	Moderate	Valley	31	3.4	24	77.4	21.2	29.5
Holman's Creek	Moderate	Valley	16	2.3	11	68.8	11.2	19.2
Holman's Creek	Moderate	Valley	14	2.4	8	57.1	11.7	17.8
Jordan's Run	Moderate	Valley	40	2.7	28	70.0	20.6	22.8
Jordan's Run	Moderate	Valley	22	4	19	86.4	20.4	37.6
Jordan's Run	Moderate	Valley	18	2.2	11	61.1	12.1	17.4
Narrow Passage	Moderate	Valley	36	2.3	21	58.3	18.1	17.6
Narrow Passage	Moderate	Valley	33	1.8	15	45.5	15.2	12.1
Narrow Passage	Moderate	Valley	32	2.3	18	56.3	17.7	17.6
Painter Run	Moderate	Valley	29	2.4	17	58.6	17	18.5
Painter Run	Moderate	Valley	29	1.8	15	51.7	13.4	12.9
Painter Run	Moderate	Valley	23	2.4	15	65.2	14.2	19.3
Riles Run	Moderate	Mountain	34	3.9	32	94.1	23.7	38.2
Riles Run	Moderate	Mountain	25	2.7	21	84.0	14.8	24.9
Riles Run	Moderate	Mountain	14	2.4	10	71.4	10.4	19.9
Mean			*26.3*	*2.6*	*17.6*	*66.9*	*16.1*	*21.7*
S.E.			*1.8*	*0.1*	*1.5*	*3.0*	*0.9*	*1.7*

Stream	Treatment	Location	Total Species Richness	Mean C	Native Species Richness	Percent Native Species	FQAI	FQAI'
Falls Run	Extensive	Mountain	22	4.5	20	90.9	21.9	42.5
Falls Run	Extensive	Mountain	20	5.4	20	100.0	24	54
Falls Run	Extensive	Mountain	17	4.8	17	100.0	19.9	48.2
Holman's Creek	Extensive	Valley	22	2.7	15	68.2	15.5	22.5
Holman's Creek	Extensive	Valley	20	3.3	16	80.0	16.5	29.5
Holman's Creek	Extensive	Valley	18	2.4	12	66.7	12.4	19.5
Jordan's Run	Extensive	Valley	29	2.8	19	65.5	18.4	22.3
Jordan's Run	Extensive	Valley	28	2.5	19	67.9	16.1	20.6
Jordan's Run	Extensive	Valley	22	2.9	15	68.2	16.5	24
Narrow Passage	Extensive	Valley	40	2.5	26	65.0	19.6	20.2
Narrow Passage	Extensive	Valley	34	2.9	23	67.6	20.6	23.9
Narrow Passage	Extensive	Valley	34	2.6	20	58.8	19.5	19.6
Painter Run	Extensive	Valley	38	2.8	25	65.8	21.6	23.1
Painter Run	Extensive	Valley	33	2.5	20	60.6	18.3	19.3
Painter Run	Extensive	Valley	23	1.8	13	56.5	11.6	13.7
Riles Run	Extensive	Mountain	35	3.3	27	77.1	22.1	28.9
Riles Run	Extensive	Mountain	31	3.8	28	90.3	22.5	36.8
Riles Run	Extensive	Mountain	21	3.8	18	85.7	18.6	34.8
Mean			*27.1*	*3.2*	*19.6*	*74.2*	*18.6*	*28.0*
S.E.			*1.7*	*0.2*	*1.1*	*3.2*	*0.8*	*2.6*

Appendix 3

List of non-native species indicating each treatment groups they were recorded in. An X in a treatment column means that that species was found at least once in that treatment group. There were a total of 85 non-native species recorded for this study. 37 of these species were recorded only in deforested sites and not found in moderately or extensively forested areas.

Non-native species	Deforested	Moderatlely forested	Extensively Forested
Acer platanoides		X	X
Agrostis gigantea	X		
Ailanthus altissima	X	X	X
Alliaria petiolata	X	X	X
Allium vineale		X	X
Amaranthus spinosus	X		
Arctium minus	X		
Asparagus officinalis	X		
Berberis thunbergii	X	X	X
Bromus arvensis	X		X
Bromus sterilis		X	
Broussonetia papyrifera			X
Cardamine hirsuta		X	
Catalpa speciosa	X		
Celastrus orbiculatus		X	
Cerastium brachypetalum	X		
Cichorium intybus	X		
Cirsium vulgare	X	X	
Commelina communis			X
Conium maculatum			X
Cynodon dactylon	X		
Dactylis glomerata		X	X
Daucus carota	X		
Dianthus armeria	X		
Digitaria sanguinalis	X		
Dioscorea polystachya	X	X	X
Dipsacus fullonum	X	X	
Duchesnea indica	X	X	X
Elaeagnus umbellata	X	X	X
Eleusine indica	X		
Elymus repens	X		
Galinsoga quadriradiata			X
Glechoma hederacea	X	X	X
Hedera helix			X
Hemerocallis fulva	X		X
Hesperis matronalis	X	X	X
Holcus lanatus	X	X	
Humulus japonicus	X	X	X
Lactuca serriola	X		
Lamium purpureum	X		
Leucanthemum vulgare	X		
Ligustrum sinense	X	X	X
Lonicera japonica	X	X	X

Lonicera morrowii	X		X
Lonicera tatarica		X	
Maclura pomifera	X	X	
Melilotus officinalis	X	X	
Mentha spicata	X		
Microstegium vimineum	X	X	X
Nasturtium officinale	X	X	X
Nepeta cataria	X		
Ornithogalum umbellatum			X
Phleum pratense	X		
Plantago major	X		
Poa pratensis	X	X	X
Poa trivialis		X	X
Polygonum cespitosum var. longisetum	X	X	X
Polygonum hydropiper	X		X
Ranunculus bulbosus	X	X	
Rosa multiflora	X	X	X
Rubus phoenicolasius	X	X	X
Rumex crispus	X		
Rumex obtusifolius	X		
Saponaria officinalis		X	
Schedonorus phoenix	X	X	
Securigera varia	X		
Silene vulgaris	X		X
Sisymbrium officinale	X		
Solanum dulcamara	X		
Sorghum halepense	X		
Taraxacum officinale	X		
Torilis japonica		X	X
Trifolium campestre	X		X
Trifolium pratense	X		
Trifolium repens	X		
Tussilago farfara	X		
Ulmus pumila	X		
Urtica dioica	X		
Verbascum blattaria	X		
Verbascum thapsus	X		
Veronica anagallis-aquatica	X		
Veronica hederifolia	X		
Veronica serpyllifolia	X		
Vinca minor		X	X

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