ASSESSING STREAM CONDITION AND LAND-OWNER VALUES TO SUPPORT CONSERVATION IN THE BROAD RIVER WATERSHED OF NORTHEAST GEORGIA

by

JASMINE NICOLE LONGMIRE

(Under the Direction of Mary Freeman)

ABSTRACT

The Broad River Watershed Association (BRWA) is a non-profit, regional land trust dedicated to the protection and management of the Broad River and its watershed in northeast Georgia. This community-based participatory research project involved collaboration between the BRWA and researchers at UGA River Basin Center to provide understanding of stream health in the Broad River watershed and to analyze results of a community survey examining landowner values, concerns, and land management activities. To assess baseline stream health, I applied mesohabitat-specific macroinvertebrate sampling methods at 15 sites distributed within the watershed and representing differing levels of support for designated use according to GA-EPD 2022 303d/305b reports. I did not find spatial patterns in macroinvertebrate abundances or species tolerances, nor associations with upstream land use. There were however significant differences in sensitive and pollutant tolerant macroinvertebrates among stream habitats, such that streams lacking riffle habitat had a lower proportion of individuals in the orders Ephemeroptera, Plecoptera and Trichoptera. Community survey data noted that most respondents were open to learning more about water quality issues and have more interactions with local organizations in comparison to state or government organizations. Many respondents were environmentally conscious with most possessing intrinsic values for their land and were not likely to do any land management in the next 5yrs. An online GIS-based "Story Map" was created to highlight the need for watershed conservation, the results of our macroinvertebrate collection, results of the community survey, and included a citizen-science focused stream health monitoring plan.

INDEX WORDS: watershed conservation, stream macroinvertebrates, landowner survey, land use

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CHAPTER 1

INTRODUCTION

Citizen perspectives can play an influential role in determining the future land management and environmental conditions of a watershed. In particular, landowners make decisions about how to use their property, potentially affecting streams and rivers among other aspects of a region's environment. Community members may also advocate with government agencies to influence policies, such as zoning, that affect environmental outcomes, or form and engage with non-governmental organizations (NGO's) focused on conservation. Meaningful engagement may be motivated by information about the status of a region's natural areas, environmental issues, and potential remedies.

This research aims to provide information to help a watershed-based NGO, the Broad River Watershed Association (BRWA), engage community members to protect the natural and scenic qualities of a river in the Piedmont region of Georgia (BRWA 2024). The Broad River Watershed spans 446 miles across 13 counties within northeastern Georgia. The Broad River watershed is primarily rural with land usage consisting primarily of temperate deciduous forest, low-density residential development, silviculture, and agricultural activities (especially cattle farming, poultry houses, and pasture/fields). Water from the Broad River flows downstream to the larger Savannah River Basin at Anthony Shoals, home to the Shoal Spider Lily (*Hymenocallis coronaria*), a well-known local attraction. The Broad River and its tributaries offer canoeing and other recreational opportunities as well as supporting valued wildlife resources. The GA Department of Natural Resources lists 73 rare plants, animals and plant communities residing in the Broad River Watershed (GDNR. 2024).

Streams in the Georgia Piedmont reflect a legacy of agricultural intensification between the 1800's to early 1900's, during which up to 30 centimeters of topsoil was lost and deposited into Georgian rivers, streams, and lakes (Meade &Trimble. 1974). Jackson et al. (2005) estimate it would take six to ten millennia to remove all farming sediment stored in Georgia's freshwater systems. These studies suggest that the current conditions of modern Piedmont streams reflect characteristics of past excessive erosion and high sediment loads that result in negative effects such as stream homogeneity and decreased ecosystem diversity (Jackson et al. 2005). These studies have expressed that historical land coverage could be a better determinate of stream health than current land coverage due to the amount of sediment in streams. A study done in the North Fork Broad River in 2006, gave results that would indicate that many Piedmont streams are unstable. Johnson (2006:17) described stable stream channels as the geomorphic "ability of a stream to withstand disturbances over time in such a manner that the stream maintains its dimensions without signs of degradation." A stable channel was characterized by healthy woody vegetation, low banks, and a flood plain that is connected to the river. An unstable stream was characterized by "sparse vegetation, steepened banks that are susceptible to mass wasting, and a flood plain that is disconnected from the channel, as a result of which the high flows remain within the channel banks." (Johnson. 2006:17). From 1900 to 2006, northern Georgia streams had characteristics as "unstable" and should still reflect these conditions today (Jackson et al. 2005).

Non-point source pollution, including sediment, is considered a major threat to water quality of streams and rivers (Novotny & Chesters 1984). In 1999, the US Environmental Protection Agency (EPA) developed a framework that provides science-based assessments and establishes Total Maximum Daily Loads, or TMDLs (Mukundan et al. 2011; EPA 1999; EPA 2006). A TDML is a calculation used to help determine the amount of waste that can be distributed back into a waterbody, which specifies the amount of a substance from point and non-point sources that can be released back into the aquatic environment without disrupting biotic and abiotic functions of the receiving ecosystem. While the TMDL system has been useful in regulating chemicals discharged into rivers and lakes, non-point sources are often not accounted for due to lack of monitoring. Other researchers have also addressed this issue as stated in Mukundan et al. 2011, "Section 303(d) of the 1972 Clean Water Act requires that each state in the United States identifies waterbodies that do not meet the required water quality standards for its designated use. For the impaired waterbodies, the state must prepare a plan to achieve a total maximum daily load (TMDL)."

Stream monitoring by governmental agencies and others can help pinpoint current, non-point sources of pollution. The Georgia Environmental Protection Division Watershed Protection Branch is responsible for regulatory management and planning for the State's water resources (GDNR, Watershed Protection Branch). The Branch also monitors stream condition for compliance with water quality standards. In 2022 GA-EPD 303d/305b listed the causes of failure to meet designated uses for 30 streams in the Broad River Watershed. Of these 30 reportedly impaired streams, 100% of impairment was due to some form of non-point source impairment. A total 446 streams miles were reported in the Broad River Watershed, 174 miles (39%) were negatively impacted with respect to fish communities or bacterial fecal coliform counts. Only 1 out of the 30 reports showed negatively impacted macroinvertebrate communities. Of the total miles assessed, 149 miles supported their designated use, i.e., majority fishing. This leaves 123 miles of stream segments with unknown health conditions (Figure 1). Supporting streams in 303d/305b documentation did not report what type of tests determined their supporting use and only 9% of streams in Georgia were assessed that year. Rural watersheds have limited resources and funding often resulting in limited water quality monitoring, leading to unregulated non-point source pollution (Mandelker. 1989).

Several non-governmental organizations, including the Riffle Beetles, BRWA, and Madison-Oglethorpe Stream Team (MOST), participate in water quality monitoring in the Broad River Watershed. These NGO's use GA-EPD Adopt-A-Stream (AAS) bacterial and water chemistry analysis for reporting water quality. BRWA has commented that, "Although sampling on a routine basis has been prevented by the pandemic, the *E. coli* counts are good in the Broad River proper but fluctuate in the tributaries" (Appendix A), possibly indicating pollution sources higher in watersheds culminating at tributaries. Previous results observed higher *E.coli* counts mostly influenced by cattle having free access to the streams, while lower *E.coli*. and higher nitrogen have been associated with chicken fertilizer provided by surrounding stack houses (Appendix A). From 2021 to late 2023, BRWA did water quality monitoring using Adopt-A-Stream protocols at 8 streams sites in Madison County and found significant fluctuation in fecal coliform counts. While bacterial assessments can be cost-effective and efficient methods, and provide good indicators of impacted sites, macroinvertebrate communities may be better at depicting a gradient of anthropogenic influences across sites (Lear et al. 2009). Additionally, while previous monitoring efforts in the Broad River Watershed have highlighted stream impairment in specific areas, watershed-wide assessments are lacking.

BRWA reached out in 2022 asking for aid in co-developing a water quality monitoring plan with the intent to conserve ecosystem services and promote citizen science. BRWA also requested help in analyzing results of a previous survey of landowners intended to identify barriers and limitations to engagement with conservation organizations like BRWA (Nelson. 2023). As a primary investigator, I partnered as an intern with BRWA beginning in 2022 under the advisement of Dr. Mary Freeman (USGS and the University of Georgia, UGA) in collaboration with BRWA Treasurer Dr. Quint Newcomer; UGA Professor, Dr. Nick Fuhrman; and Morehouse College Professor, Dr. Ethell Vereen. My goals were twofold, with one aspect focusing on stream health using macroinvertebrate indicators and the other focusing on land-owner perspectives on environmental problems and conservation. The purpose of the macroinvertebrate study was to (1) provide baseline data on macroinvertebrates inhabiting streams in the Broad River watershed and identify areas of concern; (2) examine the effects of habitat availability and land use on macroinvertebrate assemblages in southeastern Piedmont streams; and (3) compare the mean tolerance of macroinvertebrates in differing habitats, streams, and subbasins. Previous studies have used benthic macroinvertebrate assemblages and average pollution tolerance as an indicator of stream health (Deborde et al. 2016; Roy et al. 2003). Benthic macroinvertebrate functional measurements (including measures of tolerance) are also useful for identifying ecological effects of stream habitat alteration (Feld & Hering 2007). Overall, I aimed to investigate macroinvertebrate sampling to enhance our understanding of the health of streams in the Broad River watershed.

Social surveys help researchers better understand social concerns and provide us with a quantitative method of measuring levels of concern. The idea is to analyze the community's response and test correlations, such as the relationship between perceptions of environmental impairment and landowner location within a watershed. My analysis of the landowner surveys focused on assessing (1) the general demographics of the respondents; (2) how much the community knows about BRWA, and how interactions with other state or government agencies influence landowner perceptions; (3) how personal values influence attitudes toward land management; and (4) environmental concerns for the future of the watershed. Overall, this research will help highlight the health of the Broad River watershed as reflected in stream macroinvertebrates and examine needs from social surveys to determine stakeholder perspectives and concerns about the watershed.

CHAPTER 2

METHODS

Site Selection

Watershed information was obtained using federal and state entity databases. Using aerial imagery, USDA CroplandCROS, I extracted land use data for the watershed. USGS StreamStats & USGS Streamer were used to delineate a point at the mouth of the Broad River watershed, Anthony Shoals, GA, and to extract summary information about the water basin. I used the 2022 Georgia Environmental Protection Division (GA-EPD) 305b/303d reports to document stream lengths within the Broad River watershed that were categorized as supporting or non-supporting of their designated uses. Using ArcGIS, I created a map based on supporting use, non-supporting use (impaired), and unknown stream health. Using this map, I chose potential sampling sites to represent the three categories of stream condition. I aimed to compare macroinvertebrates among the three stream categories (supporting, not supporting, and unknown) along each main tributary of the Broad River system. Of 30 randomly selected sites, 10 in each category, I sampled 15 (5 in each category) that were chosen based on accessibility from roadways or permission from landowners. Several protocols used in GA- EPD Water Quality Monitoring were followed such as: avoiding the mouth of tributaries and areas of impoundment that might alter stream flow, and where possible, sampling upstream of roads or bridges.

Field Methods & Wet Lab Procedures

I used a modified version of the GA EPD Rapid Bioassessment that allows for mesohabitat assessment for our macroinvertebrate collection protocol (Barbour. 1999). Our sampling season was determined by the southeastern macroinvertebrate biological optimal period. The biologically optimal periods are when later instars of many invertebrates are most likely to be present (Plafkin et al. 1989), which in Georgia is September through February (GDNR 2007). Accordingly, I collected all samples between September 9 and December 21, 2023.

Prior to sampling at each site, I sketched a map of a 100-m stream reach that I marked with brightly colored flags or tape around stream bank vegetation at 0, 50 and 100 m. I attempted to walk parallel to the stream without unnecessarily disturbing the sample area, but due to the steepness of Piedmont banks some disturbance was unavoidable. Within each stream site, I sampled three habitats to examine the importance of mesohabitats to macroinvertebrates: sandy/silt sediment, riffle, and woody debris. I sampled each mesohabitat by collecting material in five, 1-m long jabs in or along (in the case of wood) a D-net in each mesohabitat type from different areas of the site to the extent possible. The five samples for each mesohabitat were combined in bucket and then elutriated and filtered using a 1mm sieve, with collected material placed into a labelled plastic bottle with 70% ethanol.

Samples underwent standard laboratory practices to separate and identify taxa. Using a dissecting microscope at 10x, specimens from each sample were separated from leaves and debris with tweezers and placed in a vial of 70% ethanol and labelled based on creek name, habitat type, and date sampled. Individual macroinvertebrates were identified to family level except for Collembola, Acarina, Oligocheata, and terrestrial arthropods, and recorded on waterproof datasheets. Attributes recorded include taxonomic name, number of individuals, and length of those individuals measured to the nearest 1 mm.

Macroinvertebrate QA/QC & R Analysis

Macroinvertebrates were identified and counted twice by different individuals to avoid bias in our identifications and counts of each taxon. After identification, data were coded in a spreadsheet and laboratory data sheets were compared to spreadsheet inputs to ensure the number and taxa entered for each stream and habitat were correct. For each taxon identified to family or genus, I assigned a corresponding average tolerance value derived from the regional Rapid Bioassessment Protocol and listed by GA EPD (GA-EPD. 2012). The macroinvertebrate information was exported into the software package R for analysis. The purpose of the macroinvertebrate study was to (1) provide baseline data on macroinvertebrates inhabiting streams in the Broad River watershed and identify areas of concern; (2)

examine the effects of habitat availability on species assemblages in southeastern Piedmont streams; and (3) compare the mean tolerance of macroinvertebrates in differing habitats, streams, and subbasins

To provide baseline data, I summarized the total number of aquatic macroinvertebrate and Ephemeroptera-Plecoptera-Trichoptera (EPT) individuals by mesohabitat type for each stream. These summaries excluded terrestrial insects, Collembola, Oligochaetes and pupae/eggs. I also estimated the mean tolerance value, averaged over all individuals collected in each mesohabitat type and stream, as a measure of overall macroinvertebrate pollution tolerance. I tested the differences among mesohabitats in macroinvertebrate response variables (total abundances, EPT abundances and mean tolerance) using mixed-effect linear regression, with habitat type as the fixed effect and stream identity as a random effect (to account for multiple samples within streams). I also tested for effects of upstream watershed land use on macroinvertebrate response variables by habitat type using linear regression. Finally, to visualize spatial patterns in macroinvertebrate response variables, I plotted outcomes for streams ordered by subbasin, from the upper to lower portions of the Broad River basin.

Social Survey & IBM SPSS Analysis

The landowner survey was created by Alec Nelson, using a mixture of descriptive statistics, nominal scales, ordinal scales, and Likert Scales to better understand landowner-watershed interactions in the Broad River Watershed. The purpose of this survey was to help determine pitfalls and barriers that limit guidance, resources, and communication to landowners related to watershed planning (Nelson 2023). Using IBM SPSS, I analyzed data to ask a series of questions about landowner- watershed interactions. This software was previously piloted to test for validity and reliability using our data to determine correct scaling and averages. Survey responses were converted into binomial, nominal, and ordinal scales to allow for statistical analysis. The database was filtered to determine the number of surveys received [Data→Select Case→If condition satisfies @0no1yes=1]. Filtering was used to remove no entry answers of 999 which were placed holders for unanswered questions [Transform→Recode into same variables→ 999->SYSMIS]. These unanswered questions had to be recoded to avoid adding 999 to our calculations. If I were to leave the 999's the results would be incorrect and skewed. To validate our results, we confirmed the scales of each question and removed any numerical values outside that scaled range e.g. scale of 1-5, we'd remove 44 and change it to 4 to better represent the present scale. Demographics statistics were analyzed using frequency tables for variables such as age, sex, land owned, and education. Independent sample T-tests were created to test the relationships between recipients' values and current or future land management with the purpose to compare sample means. The Cronbach alpha test was used to determine how reliable or alike objects in a group were. This test is used to "assess the degree to which the individual questions that were grouped together (in this case according to "motivations") actually measured a similar underlying factor" (Geroge & Mallery. 2003). A score of 0.7 or greater on a scale of 0 to 1 is a strong indication that the questions are measuring a similar factor. Constructs were built to test groups examining watershed values, water perspective, current land management and future land management, knowledge about the BRWA or interactions with other state or governmental entities, and concerns for the future.

CHAPTER 3

RESULTS

Macroinvertebrate assemblages in relation to habitat conditions and land use

Stream impairment, as reported by 2022 GA-EPD 305b/305d documentation, was widespread across the Broad River watershed. Over half (170 miles) of the tested streams were assessed as “impaired”, compared with 146 miles assessed as supporting designated uses. Figure 1 used 2022 GA-EPD 305b/305d documentation that provides the length and location of impaired streams in “red”, supporting streams in “green” and unknown stream health in “blue” (Figure 1). My sampled stream sites were located across the watershed, with 2 in the North Fork, 1 in the Middle Fork, 2 in the Hudson, 5 in the South Fork, and 4 sites in the Broad River (Figure 2). Sites representing “impaired” streams and sampled for macroinvertebrates were in the South Fork and Broad River.

From our mesohabitat sampling I gathered 9 samples from riffle, 15 samples from sand/silt, and 14 samples from woody debris. Seven streams had two available habitats, while the other eighht had all available habitats. I collected a total of 4,027 macroinvertebrates, representing 15 orders and 52 identified families (Appendix B). I identified individuals from 9 families of Ephemeroptera, 9 families of Plecoptera, and 7 families of Trichoptera. The family with the highest count was Chironomidae with a total of 1,512 individuals. Total aquatic macroinvertebrates collected ranged from 84 to 630 individuals across the 15 streams and were generally higher in the streams that also had riffle habitat (Figure 3). I collected a total of 712 individuals from the Order Ephemeroptera, 336 Plecoptera individuals, and 483 Trichoptera individuals. The median number of EPT individuals collected across streams was 100 and again was generally higher in streams with riffle habitat (Figure 4). In comparison to other streams, highest EPT totals were in Stephen Creek at 218, Sulphur Springs Creek at 364, and Unawatti Creek at 142 (Figure 4). Mean individual tolerance ranged between 3.83 from Sulphur Springs Creek to 6.51 from Nails Creek (Figure 5).

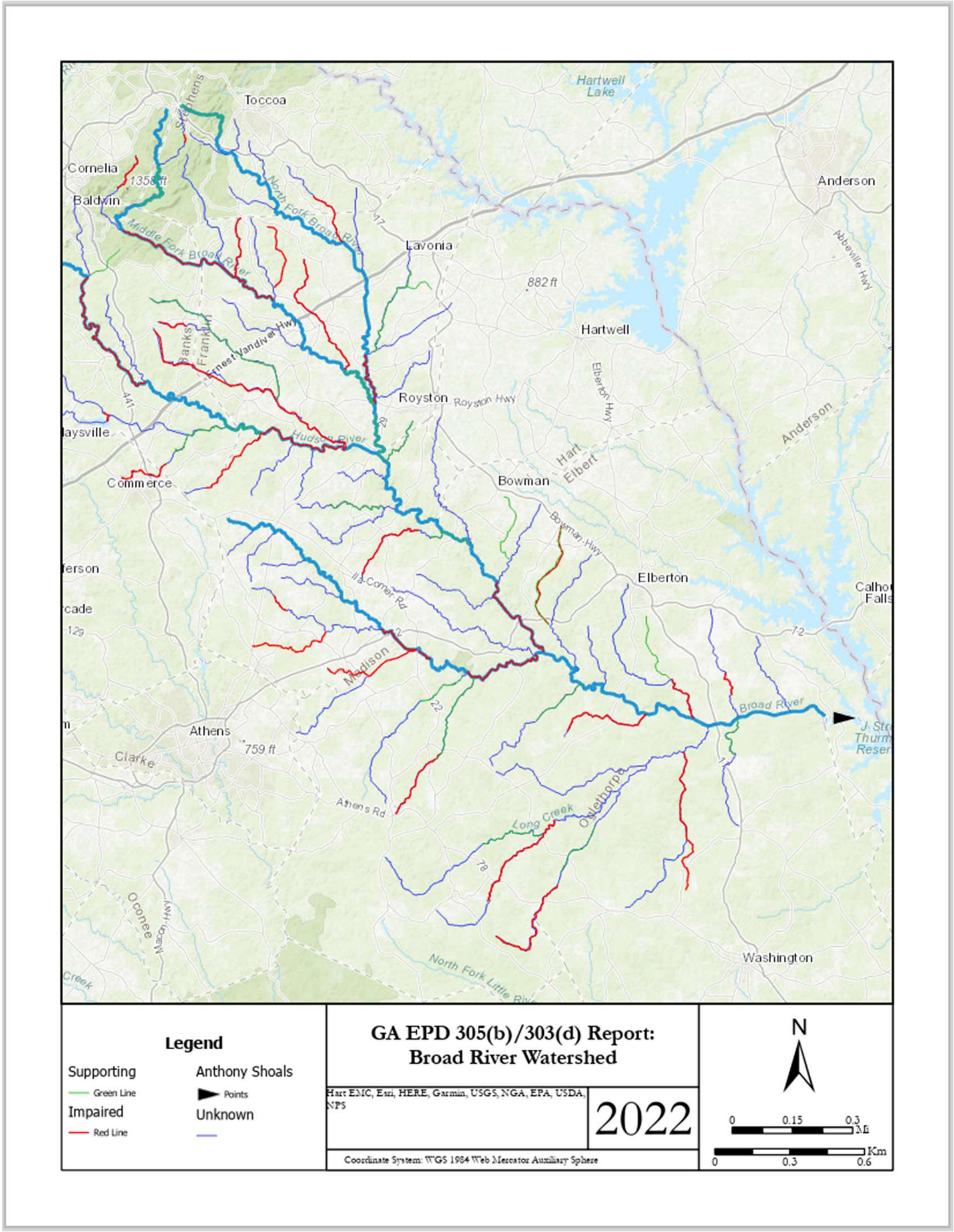

Figure 1: Map of the Broad River watershed highlighting impaired streams in "red", supporting streams in "green" and unknown streams in "blue"

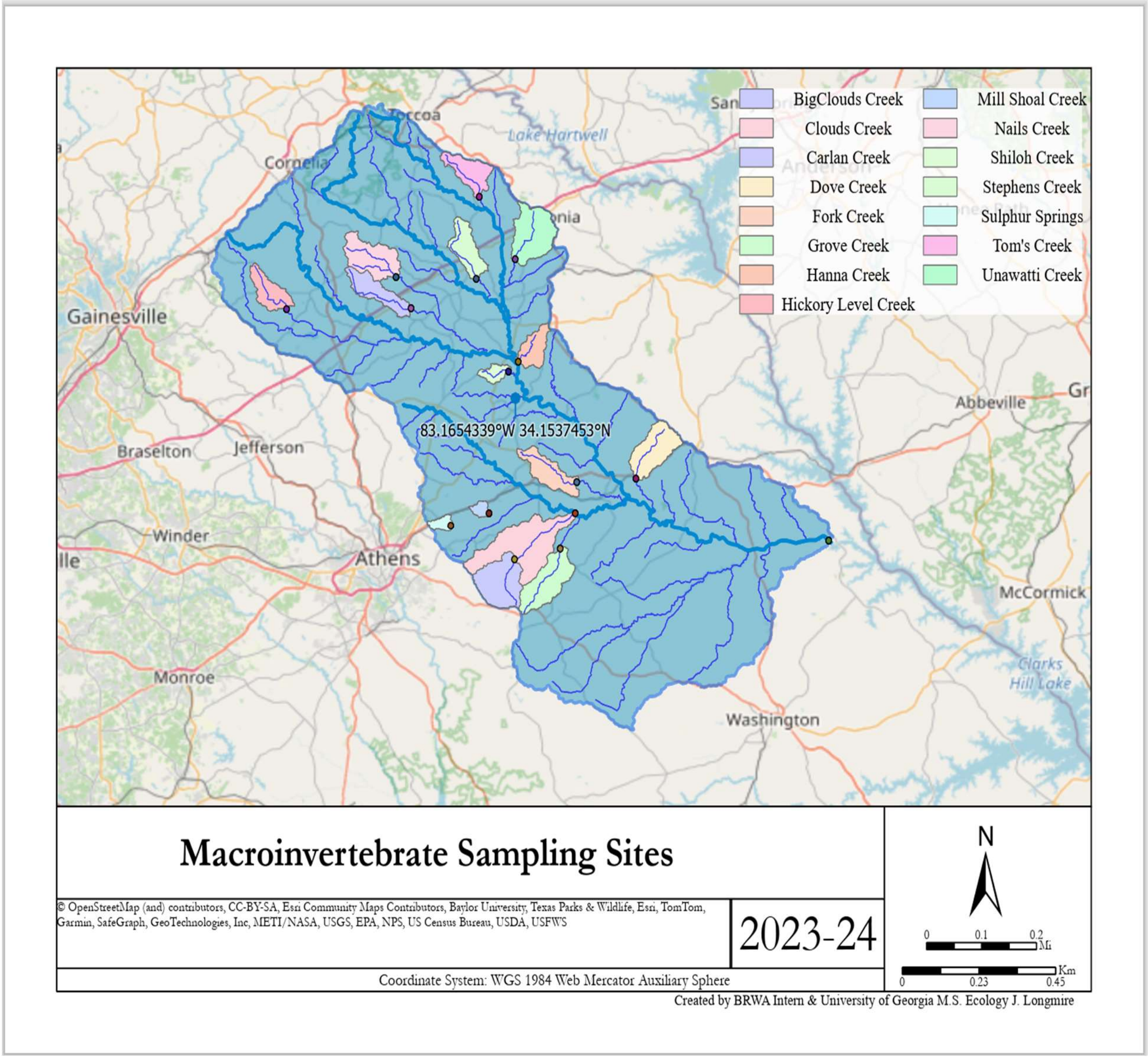

Figure 2: Sites sampled for macroinvertebrates in 2023 and the upstream basin associated with each site; 15 sites were chosen with 6 in the Upper Basin and 9 in the Lower Basin Broad River Watershed

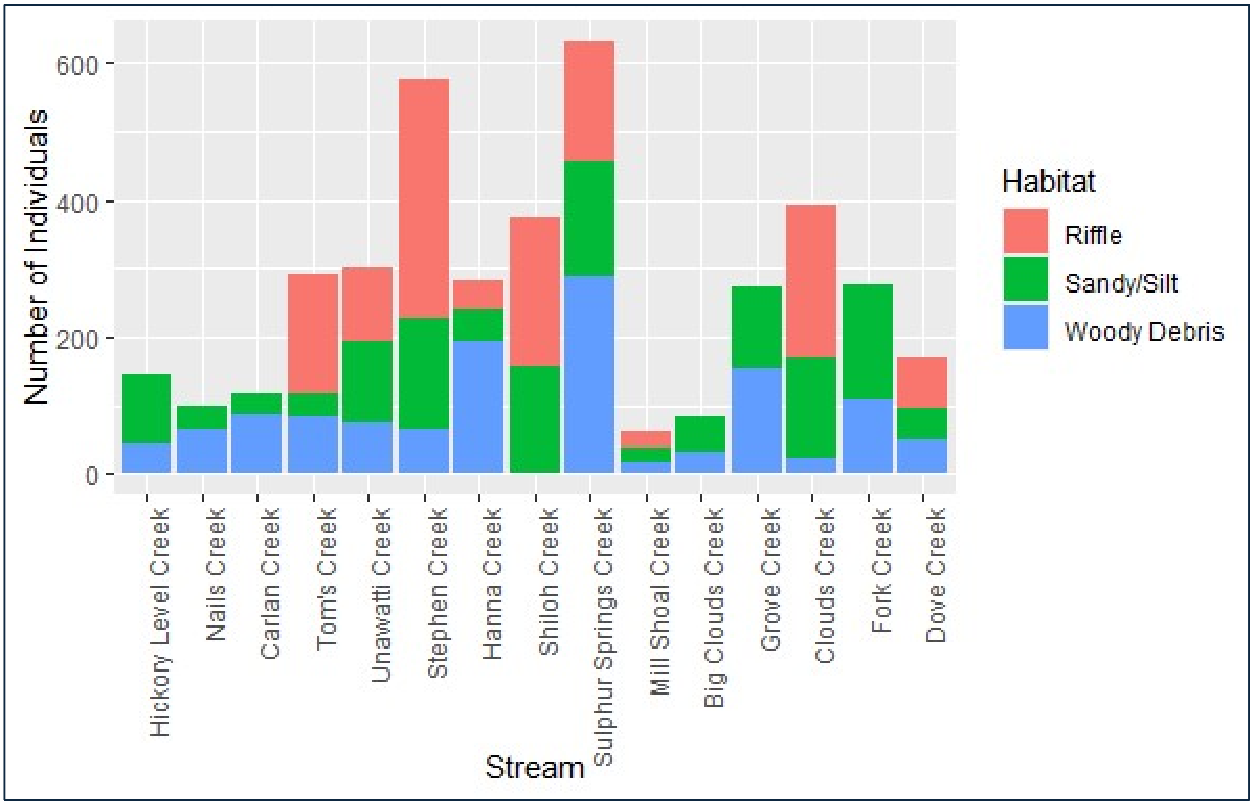

Figure 3: Total number of individuals collected from available habitats per stream. The graph depicts streams in order of spatial location within the watershed going from the Upper to Lower basins

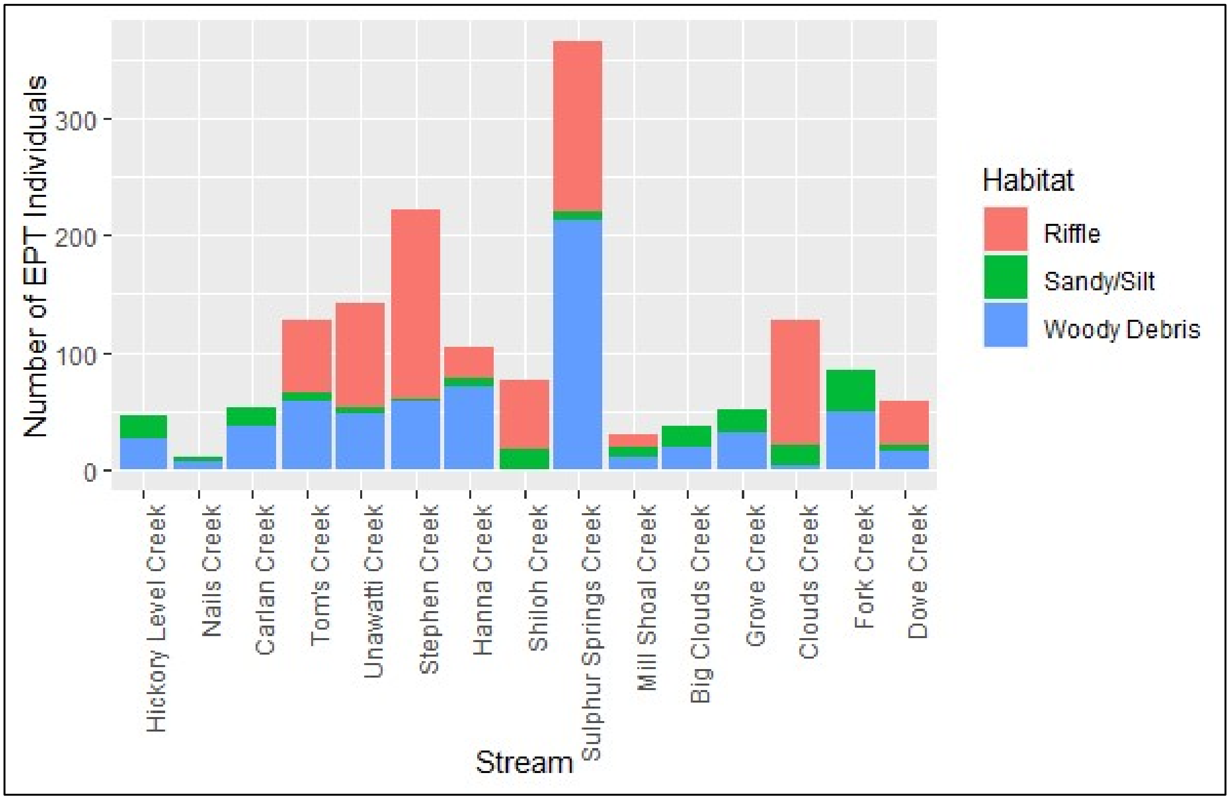

Figure 4: Total number of EPT individuals collected from available habitats per stream. The graph depicts streams in order of spatial location within the watershed going from the Upper to Lower basins.

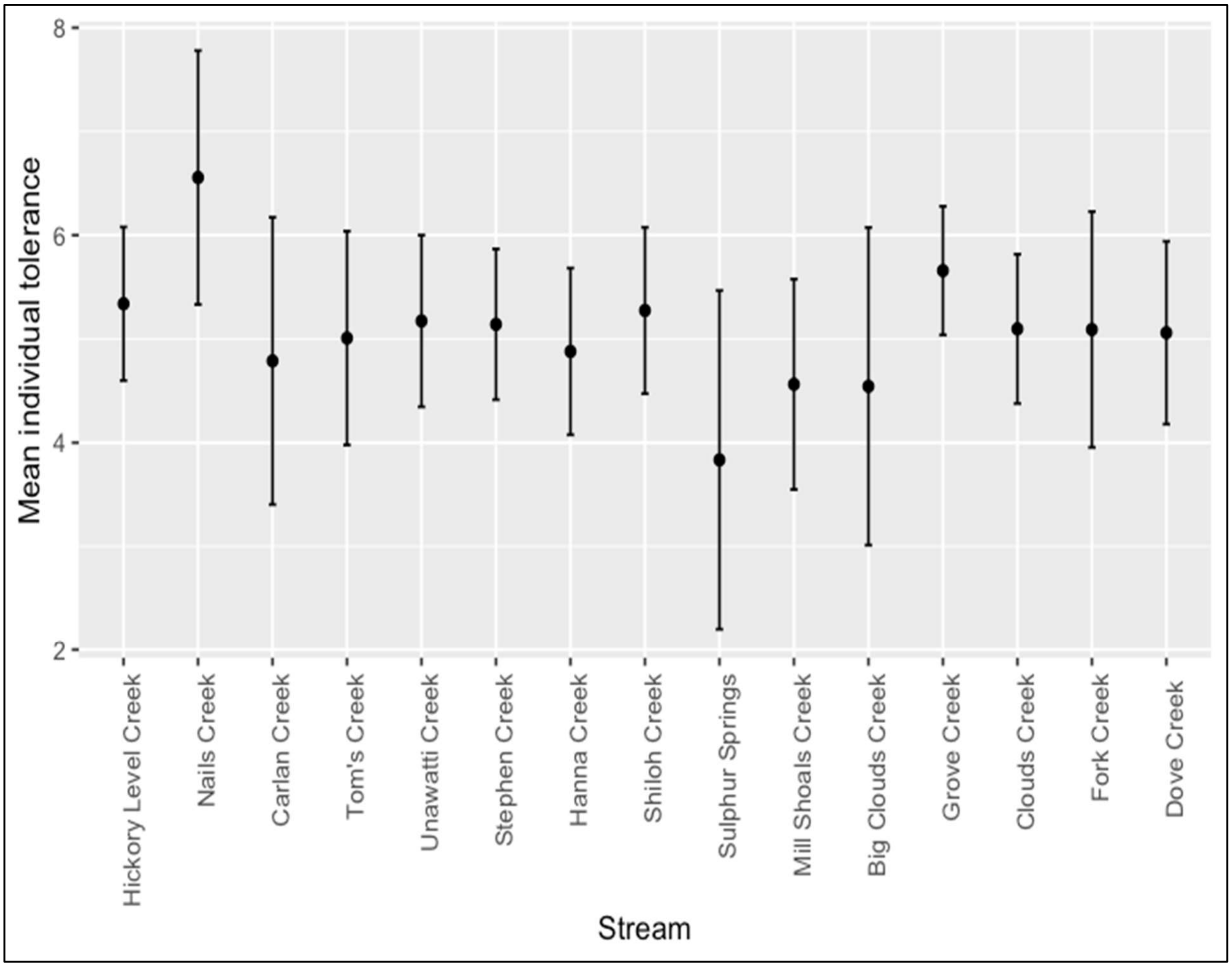

Figure 5: Average and standard error of the mean individual tolerance across streams. The average mean tolerance across all streams was 5.01. The graph depicts streams in order of spatial location within the watershed going from the Upper to Lower basins.

The three mesohabitats differed in macroinvertebrate total, EPT individuals, and average tolerance values. The estimated differences between total macros between riffle compared with sand and woody debris were significant at a 95% confidence level. There was a higher average number of total individuals from riffles (n = 154), while sand habitat (n = 93.7) had a lower average of individuals in comparison to riffles. Woody debris had the lowest average individuals (n = 91) (Figure 6-A). The estimated differences between total EPT macros between riffle compared with sand were significant at a 95% confidence level. The average number of total EPT were highest in riffle samples (n = 77) and lowest in sand/silt individuals (n = 12.6). Woody debris was slightly lower than riffles (n = 46.8) (Figure 6-B). The estimated differences between average tolerance between riffles compared with sand were significant at a 95% confidence level. Individuals in sand (n = 5.6) were overall higher in tolerances values than riffle (n = 4.5) and woody debris (n = 4.6). Riffles had the lowest mean tolerance (Figure 6-C).

I did not test for an effect of forest land use because the percentages of forest and of agricultural land had a strong a correlation of -.95 (Figure 7-A). There was little correlation between percentages of urban vs. forest land cover or urban vs. agriculture (Figure 7-B and C). Percent agricultural land use had no strong influence on macroinvertebrate individuals collected across differing habitats, habitat EPT totals, and mean individual tolerance (Table 1). Percent urban land use similarly had no strong influence on macroinvertebrate individuals collected across differing habitats, habitat EPT totals, and mean tolerance (Table 2). The proportion of all individuals that were EPT (“proportion EPT”) was nearly the same between the upper and lower basin (Figure 8). However, the proportion EPT was higher in streams with three habitats than in streams with only two habitats (Figure 9). Mean individual tolerance also ranged lower in streams with three compared with two habitats (3.38 - 5.15, vs. 4.87- 6.51).

A

B

C

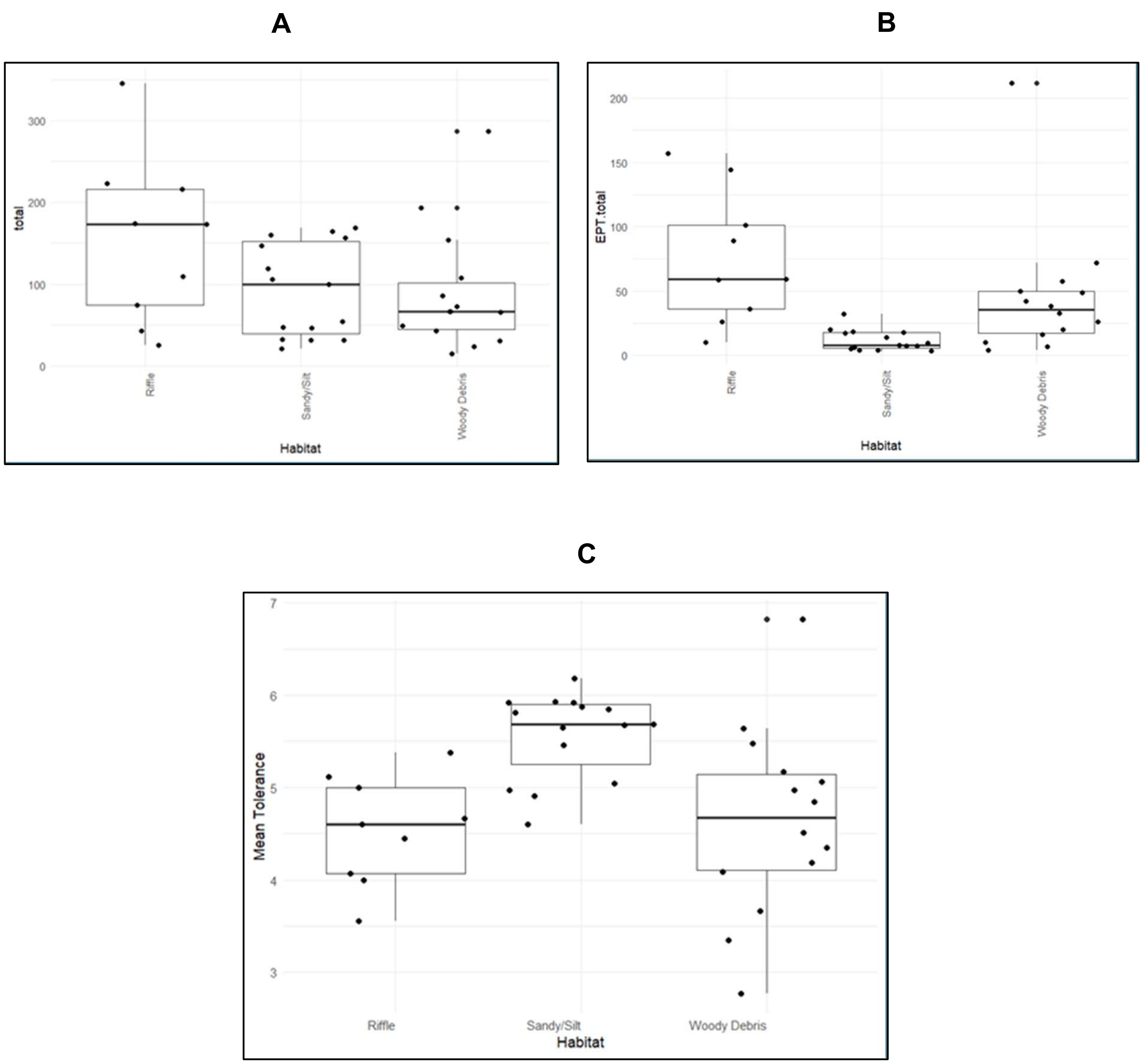

Figure 6: Comparison of (A) macroinvertebrate totals, (B) EPT total individuals, and (C) mean tolerance of individuals among habitats. Boxplots show the mean and interquartile range, with individual sample values plotted as points.

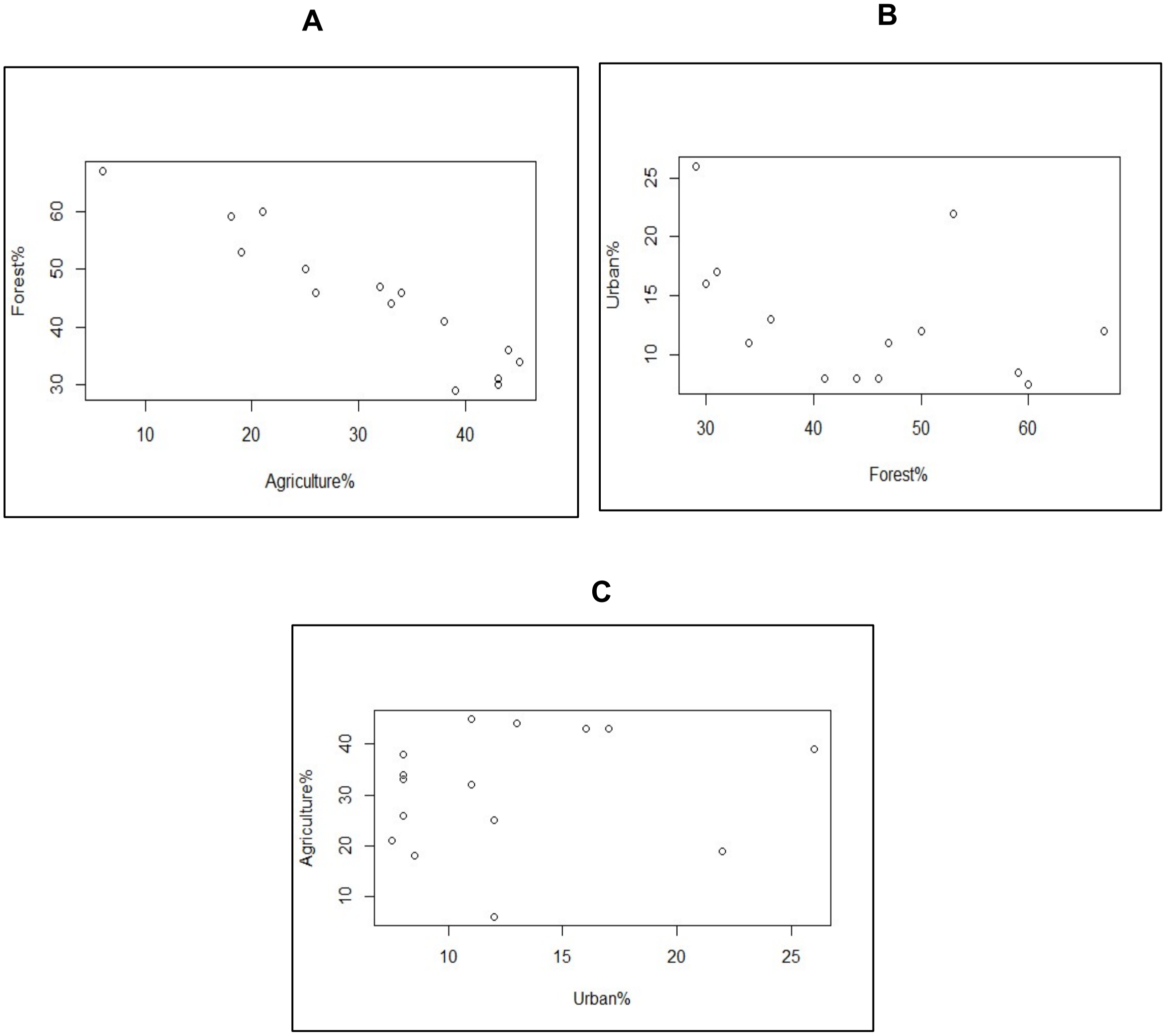

Figure 7: Land use upstream of sampled sites: A. Forest vs Agricultural; B. Forest vs Urban; C. Agricultural vs. Urban

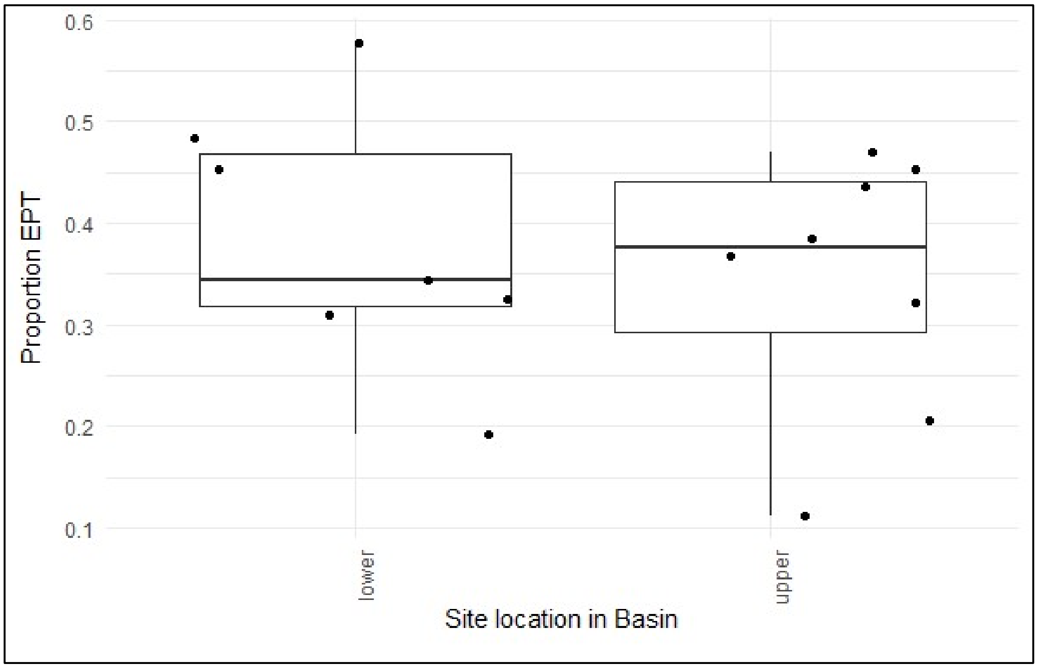

Figure 8: Proportion of all individuals that were EPT in sites located in the upper and lower portions of the Broad River basin.

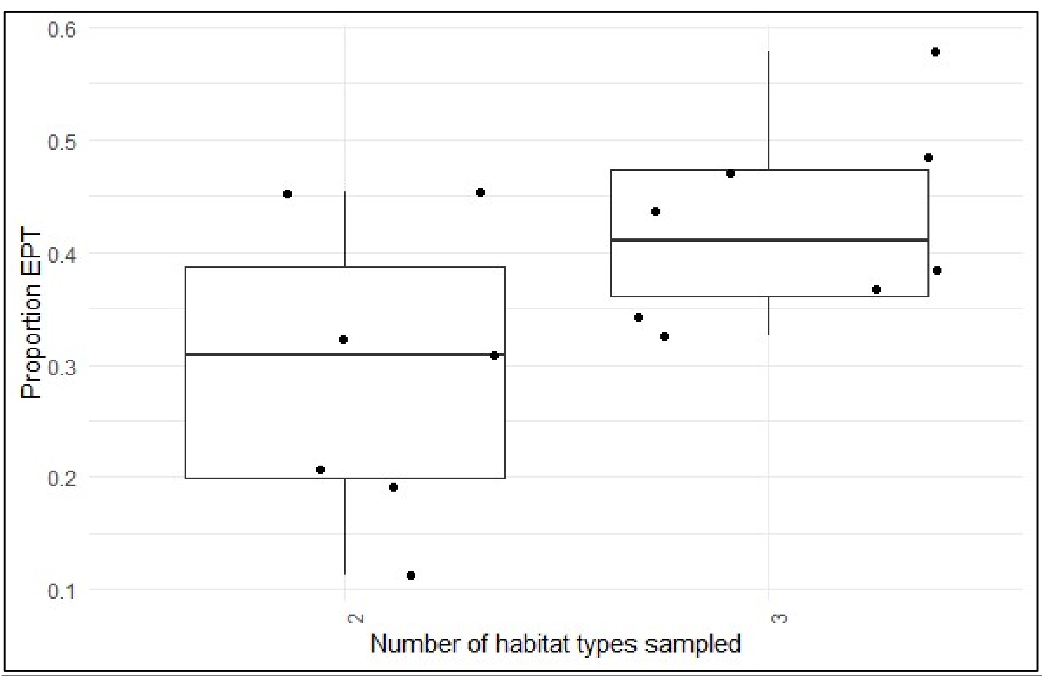

Figure 9: Proportion all individuals that were EPT from streams with 2 compared with 3 habitats.

Table 1: Regression results for effects of proportion of the upstream watershed in agricultural land use on habitat-specific macroinvertebrate and EPT totals and mean individual tolerance. The number of streams with samples for each response variable is listed as "n." Standard errors for the regression parameter estimates are shown in parentheses; t values and probabilities test whether the regression slope is different from 0.

Response variable	n	Intercept	Slope	t	Pr (>|t|)
Total # individuals, Riffle	9	68.1 (97)	2.18(2.86)	0.764	0.470
Total # individuals, Sand	15	47.6 (42.6)	1.46(1.29)	1.13	0.277
Total # individuals, Wood	14	146.4 (58.3)	-1.82 (1.82)	-0.999	0.337
EPT total # individuals, Riffle	9	48.32 (115.8)	2.39 (3.415)	0.699	0.507
EPT total # individuals, Sand	15	56.7(49.2)	0.842 (1.491)	0.565	0.582
EPT total # individuals, Wood	14	143.7 (62.8)	-2.092(1.956)	-1.069	0.306
Mean individual tolerance	15	5.62 (0.32)	-0.048 (0.023)	-2.044	0.062

Table 2: Regression results for effects of proportion of the upstream watershed in urban land use on habitat-specific macroinvertebrate and EPT totals, and mean individual tolerance. The number of streams with samples for each response variable is listed as "n." Standard errors for the regression parameter estimates are shown in parentheses; t values and probabilities test whether the regression slope is different from 0.

Response variable	n	Intercept	Slope	t	Pr (>|t|)
Total # individuals, Riffle	9	220.96	-4.42 (6.548)	-0.675	0.521
Total # individuals, Sand	15	76.7	1.27 (2.83)	0.447	0.662
Total # individuals, Wood	14	54.2	2.84 (3.68)	0.774	0.454
EPT total # individuals, Riffle	9	73.6	0.212 (3.367)	0.063	0.952
EPT total # individuals, Sand	15	17.4 (5.25)	-0.475 (0.385)	-1.23	0.239
EPT total # individuals, Wood	14	-6.24	4.139 (2.32)	1.787	0.0992
Mean individual tolerance	15	5.15 (0.425)	-0.047 (0.013)	-0.364	0.722

Results of Social Survey Questions

Respondents (n= 373) were evenly distributed throughout the watershed. There were two times more male respondents than female respondents. The average age of respondents was 54.7 years (std. = 1.357). The average length of time people owned their land was between 11-30 yrs and most people owned less than 100 acres. Respondents were not likely to do any substantial management on their land in the next 5 years (Table 3). Most respondents (66.6%) reported having heard of or knowing about BRWA and at least half considered BRWA a local organization that benefits natural resources. All most half (49%) of respondents had neutral trust in the types of conservation work BRWA participated in and in the clarity of communicating this information to the public. Forty-two percent of people found that transparency about the conservation work being done was their biggest barrier. While fifty six percent reported little or no barrier in participation. Knowledge about other agencies increased the likelihood of knowing about BRWA. Local and Regional NGOs were the only organizations that had an influence on local stewardship (Table 4). On an environmental scale from 0 (no concern for protection of the environment) to 10 (ultimate concern for protection of the environment) respondents primarily ranked between 5 to 7. Survey respondents reported 50% agreement with concern for the future regarding protection of drinking water, keeping land in families, and high property taxes. A large majority agreed in the protection of clean drinking water, groundwater, rivers/lakes, and marine water. The top three water issues were: protection of private wells, fish and wildlife needs, and watershed management. The top significant reasons for valuing private land were scenery, privacy, and to be able to pass land on to heirs (Table 5).

Landowner values have an influence on land management. When examining how conservation-specific land management activities related to landowner values. I found that any type of firewood removal and timber were less likely to occur due to low importance (e.g., scores of < 2 on a scale of 1-5, regardless of engagement in conservation management; Table 6). Values such as enjoying nature or scenery ($\bar{x}$ = 4.21), protection of nature ($\bar{x}$ = 4), and privacy ($\bar{x}$ = 4.13) were of high importance and primary reasoning for improving wildlife habitats. Values such as privacy ($\bar{x}$ = 4.1), raising families ($\bar{x}$ =

3.72), and recreation ($\bar{x}$ = 3.48) were of highest importance and had direct correlation with water quality management. When comparing trail construction to respondent values, scenery ($\bar{x}$ = 4.21), protecting nature ($\bar{x}$ = 3.9), and privacy ($\bar{x}$ = 4.22) were found to be of high importance to the community. In comparison, any activity involving firewood ($\bar{x}$ = 1.95) or timber ($\bar{x}$ = 1.92) in relation to trails, were again considered significantly less important scoring < 2 on the 1-5 scale (Table 6).

Table 3: General demographic statistics for BRWA Social Survey respondents

General Recipient Demographics		
Question (?)	Descriptor	Percentage (%)
How many surveys were received back?	Received 374 out of 3215	11.6%
What percentage of respondence from each county?	Madison County	22.7%
	Franklin County	18.4%
	Oglethorpe County	17.6%
	Elbert County	17.4%
	Banks County	15.8%
	Stephens County	4.5%
	Wilkes County	3.5%
What percentage of female vs. males responded?	Females	28.6%
	Males	65.1%
What is the age range within the watershed?	Under 21	0.3%
	21-29	1.1%
	30-39	3.4%
	40-49	7.7%
	50-59	19.6%
	60-69	31.8%
	70-79	25.6%
	80-89	8.5%
	90 and above	2%
What is the average time of land owned?	Less than 1yr	0.8%
	1-5yrs	13.9%
	6-10yrs	12.3%
	11-20yrs	25.1%
	21-30yrs	15.6%
	31-40yrs	13.9%
	41-50yrs	7.9%
	51-60yrs	4.1%
	61+yrs	6.3%
What was the average amount of land owned?	0-100 acres	67.9%
	100-250 acres	19.3%
	500 acres or more	6.3%
How many people rely on their land for living expenses?	Only 7% of respondents rely on more than 41% of their land for their livelihood	
What type of outdoor recreation do people participate in?	Hikes	60%
	Nature Walks	52%
Current Land Management?	Eliminate Invasives	46.5%
	Herbicides or Pesticides	45.2%

	Improve wildlife habitat	41.9%,
	Trails	39.7%,
	Installed food plots	38.8%
	Water quality management	37.3%.
Future Land Management?	Most activities had 50% or more participants who were not likely to participate in significant land management in the next 5 years.	
Top Environmental Concerns	Industry	52.4%
	Stormwater Runoff	41.7%
	Erosion	41.1%
	New Suburban Development	34.5%

Table 4: Survey respondent interaction and understanding of BRWA

Knowledge about BRWA from Respondent Perspectives		
Question (?)	Descriptor	Percentage (%)
Did you know about BRWA before this survey?	Never heard of BRWA	33.4%,
	Have heard the name	28%,
	Somewhat know the name	27.1%,
	Knew it well	6.2%
	Members	5.3%
Is BRWA a part of the local community?	agree to strongly agree	55.9%
	neutral	37.1%
	disagree to strongly disagree	7.1%
Do local organizations benefit natural resources?	agree to strongly agree	69.6%
	neutral	26.2%
	disagree to strongly disagree	4.1%
BRWA's communication clarity?	agree to strongly agree	22.4%
	neutral	54.8%
	disagree to strongly disagree	22.7%
Trust in BRWA's work?	agree to strongly agree	40.9
	neutral	49%
	disagree to strongly disagree	10.1%
How do you receive information about the watershed? (chose 3 items from a list of 14)	Friends/Family	60.2%
	Local Paper	57.2%
	Extension	33.8%
	Environmental Groups	23.9%

How much of a barrier is their participating with BRWA? (moderate to major barrier)	Unsure about conservation work	42.1%
	Reported limited or no information	54.2%
	Takes up too much time	40.1%
	Saw no or little barrier	59.9%

Knowledge about Other Agencies and Respondent Perspectives	
Relationship	P-value
Knowledge about other agencies has a direct relationship to knowing more about BRWA	p=<.0001
Only Prior Interactions with local or Regional NGO showed statical significance on stewardship	p= <.001

Table 5: Percentage of agreement from recipients regarding Personal Values and concern about water issues, watershed, and private land

Personal Values and Concerns		
Category	Descriptor	Percent Agreement (%)
Watershed Concerns	Protecting drinking water; keeping land intact in the future; High property taxes	57.3%, 56%, 54.3%
	Vandalism/dumping; trespassing	47.9%, 44.8%
	Government regulation; nearby land development; drought	43.9%, 40.3%, 38.2%
	Agricultural waste contamination; air pollution; invasive insects; Wildfire	32.8%, 29.9%, 26.5%, 25.8%
	Invasive plants; Climate change; non-resident recreation	24.7%, 22.9%, 22%
Water Use	Clean Drinking water	85.2%
	Clean groundwater	73.6%
	Clean River/Lakes	62.8%
	Clean Marine Water	59.7%
	Water for Agriculture	44.7%
	Water for Recreation	32.5%
	Municipal Use	29.1%
Water Issues	Marked no water quality issues	21.1%
	Marked 2 to 3 water quality issues	29.6%
	Private wells	41.3%
	Fish and wildlife needs	32.8%

	Watershed Management		31.6%
Receptiveness to learning about Water Issues	Visiting a website		69.9%
	Read a newspaper article		41.4%
	Read Printed fact sheets and brochures		58%
Environmental Scale	environmental scale 1 out of 10, averaged between 5 and 7	5	38.1%
		6	12.5%
		7	14.8%
Private Land Value (highest percentages)	Scenery or Beauty		43.7%
	Privacy		42.1%
	To pass land to children or heirs		40.4%
	To protect nature		33.6%

Table 6: Influence of landowner values and concerns on current land management. Mean scores (on a scale of 1-5) are shown for respondents who reported implementing ("yes") vs. not implementing ("no") each land management activity are shown for selected reasons for owning land (Values), along with the 95% confidence interval for the difference between the means and associated p-value.

Stakeholder Relationship between Values and Conservation Land Management		
Land Management	Values Relationship (scale 1-5)	Mean; 95% confidence interval; p-value
Improve Wildlife Habitats	Enjoy Beauty or Scenery (yes=150, no=198)	4.21 vs. 3.83; (-0.6, -.16); p < .001
	Protect Nature (yes=149, no= 199)	4 vs. 3.53; (-0.71, -0.24); p < .001
	Protect water resources (yes=149, no=195)	3.85 vs. 3.44; (-0.64, -.17); p < .001
	Privacy (yes=150, no=197)	4.13 vs. 3.82; (-0.56, -0.063); p = 0.014
	Firewood (yes=150, no= 200)	1.97 vs. 1.64; (-0.55, -0.13); p = 0.002
	Frequent Harvest of forest product (yes=149, no=199)	1.89 vs. 1.49; (-0.62, -0.18); p < .001
	Timber (yes=149, no=201)	1.91 vs.1.6; (-0.543, -0.065); p = 0.013
	NTFP harvest (yes=149, no=198)	1.71 vs. 1.45; (-0.46, -0.050); p = 0.02
	Hunting (yes= 150, no=202)	3.46 vs. 2.41; (-1.35, -0.75); p < .001
	Fishing (yes=149, no=199)	2.58 vs. 2.12; (-0.76, -0.17); p = 0.002
	Recreation (yes=150, no=198)	3.57 vs. 2.92; (-0.91, -0.37); p < .001
	Privacy	4.1 vs. 3.86; (-0.49, 0.02); p = 0.071

Water Quality Management	(yes=131, no=213)	
	Raising my family (yes=129, no=213)	3.72 vs. 3.23; (-0.813, -0.16); p = 0.004
	Frequent Harvest of forest product (yes=131, no=215)	1.89 vs. 1.52; (-0.6, -0.15); p = 0.001
	Timber (yes=131, no=217)	1.97 vs.1.58; (-0.63, -0.15); p = 0.002
	Hunting (yes=131, no=218)	3.11 vs. 2.7; (-0.74, -0.083); p = 0.014
	Recreation (yes=130, no=215)	3.48 vs. 3.05; (-0.701, -0.15); p = 0.003
Trails	Enjoy Beauty or Scenery (yes= 141, no=207)	4.21 vs. 3.88; (-0.554, -0.1); p = 0.005
	Protect Nature (yes=140, no=208)	3.9 vs. 3.62; (-0.532, -0.036); p = 0.024
	Privacy (yes=140, no=207)	4.22 vs. 3.77; (-0.702, -0.205); p < 0.001
	Firewood (yes=141, no=209)	1.95 vs. 1.66; (-0.51, -0.07); p = 0.011
	Timber (yes=141 , no=210)	1.92 vs. 1.60; (-0.56, -0.081); p = 0.009
	Hunting (yes=141, no=211)	3.15 vs. 2.66; (-0.812, -0.163); p = 0.003
	Recreation (yes=141, no=207)	3.62 vs. 2.92; (-0.98, -0.424); p < 0.001

CHAPTER 4

DISCUSSION

The purpose of this study was to assess the health of the Broad River Watershed using macroinvertebrate communities, and to understand stakeholder environmental concerns and attitudes towards conservation through surveys. There were minor differences in macroinvertebrate communities among steams that can be connected to local habitat conditions. Widespread historical agriculture can also explain why the current percent agricultural or urban land use did not correlate with macroinvertebrate metrics. Differences in habitat availability were found among streams and these affected macroinvertebrate communities. Riffles had the highest total abundances of EPT individuals, while sand had the highest total number of individuals. Sand habitats also had higher mean tolerances than riffle and woody debris. In streams with all three habitats, the mean pollution tolerance was relatively lower and proportional representation of EPT taxa higher compared to streams lacking riffle or woody debris habitat. This indicates that streams with riffle habitats had more sensitive species and may be healthier than streams with only two habitats. Stakeholder values and concerns appeared to influence certain current land management activities. Overall, however, survey respondents were 50% or more likely not to participate in any future land management in the next 5 years. The top environmental concern was industry which could represent a variety of activities across the watershed such as solar farms, timber mills, industrial companies, and quarries. Most participants had limited interactions with state or government agencies, and primarily interact with local NGO's. BRWA is considered a part of the local community in advocating watershed conservation, but the work done, and information communicated to the community is considered unclear.

Macroinvertebrates are exceptional pollution indicators with taxa having differing levels of sensitivity. The more sensitive the species, the lower the pollution tolerance number (Barbour et al. 1999; GA-EPD 2012). Many macroinvertebrates are aquatic larvae that live in a local stream system for months to a year until they emerge into their adult form, and so may be exposed to even periodic episodes of poor water quality. Studies have also emphasized the importance of visual analysis of habitats as part of stream assessment (Silva et al. 2014). A study in 2014 found that mesohabitats and stream sites combined can explain up to 32 % of total variation in macroinvertebrate assemblages. Stream location explained up to 11 %, and differences in surface flow accounted for more than 60 % of variation among mesohabitats (Silva et al. 2014). In my study, we found location in the watershed had no obvious effect on macroinvertebrate condition. The proportion of macroinvertebrates that were in the EPT orders were similar in streams from upper and lower portions of the basin. However, the number of habitats within streams had a significant impact on EPT proportion, which was higher in streams with all three habitats in comparison to two-habitat streams. Based on these findings, I infer that streams of concern (i.e., supporting fewer sensitive taxa) in the Broad River Watershed can best be determined based on the number of available habitats. These EPT proportions also indicate that mean tolerance of three-habitat streams will be lower due to having a higher abundance of pollutant sensitive species. Riffles had significantly more total EPT individuals in comparison to sand habitats, which had significantly higher mean tolerances and total individuals. This emphasizes the support of more pollution tolerant macroinvertebrates in sand habitats and more pollutant sensitive species in riffles. In a study done in 2019, streams with land use similar to Piedmont streams with narrow riparian buffers and high agricultural land use had a higher number of pollutant tolerant macroinvertebrate species (Effer-Fant et al. 2019). The results of Effer-Fant and our own sampling reflect how intensely altered land use can influence stream habitats and the pollutant tolerance of macroinvertebrates that reside in those habitats. I found riffles and woody debris had macroinvertebrates with lower mean tolerances values than sandy habitats. A study of land use and habitat effects on streams in Great Lake watersheds also found that outside of riffles, woody debris had a strong relationship with macroinvertebrate assemblages (Richard & Host. 1994).

Streams in the Georgia Piedmont have what many have called a “sediment legacy.” Late 90’s to early 2000’s research characterized how agricultural cropland intensification from the early 1800’s to the 1900’s influenced streams (Jackson et al. 2005). Wolman stated, “land was converted from forest to cropland and reached a peak of sediment production in early 1900's…Sediment reduction declined after farming allowing cropland to revert to forest and pastures" (Meade & Trimble. 1974). Decades of intensive row crop farming resulted in inches of topsoil runoff into freshwater systems. Our sampled streams in the Broad River watershed reflect this historical legacy with excessive sand/silt and incised channels between high, often eroding banks. In a land-use legacy study on 12 small streams in Fort Benning, Georgia researchers found that certain stream conditions can be explained by current land use but when adding past land-use variables, other biotic and abiotic aspects were more closely related to past land use (Maloney et al. 2008). In Maloney's research, percent of restored land use from agriculture to forest shown a positive correlation with "streambed instability, a macroinvertebrate biotic index, and fish richness" (Maloney et al. 2008). A study modeling the influence of urbanization and land use on fish species occurrences in another Piedmont basin found that historical and current land use were also essential in determining fish communities (Wenger et al. 2008). Land cover relationships between forest percentage and agricultural percentages had a direct inverse relationship for the sites sampled in the Broad River watershed, but land cover had no discernable effect on macroinvertebrate communities. When comparing different land coverage percentages against habitat-specific macroinvertebrate totals and mean individual tolerance values, I found no significant relationships. The lack of land use relationships can also be explained based on spatial scale of sampling, in which land use closer to the sample area could better reflect macroinvertebrate conditions. In other studies, it was found that biotic communities were most closely related to local-watershed scale sampling because it allows for better understanding of how habitats and disturbances influence biotic community assemblages (Sponseller, et al. 2008; Walters et al. 2003).

Landowners responding to BRWA's survey scored relatively high on the environmentally-friendly scale. Many respondents were interested in the types of resources that would provide more information or training in water issues, such as visiting a website or reading a newspaper article on the subject. A 2014 social survey of rural landowners found that landowners had a greater willingness to try to participate in conservation efforts, but limited financial support and lack of familiarity with water issues and local conservation organizations become a significant barrier in community participation (Perry-Hill and Prokopy. 2014). Among Broad River survey respondents, landowner values had correlations with land management. The top reasons for valuing land were scenery, privacy, and to be able to pass land on to heirs. When examining conservation-specific land management activities in relation to landowner values, I found that any type of firewood removal and timber were less likely to occur due to low importance.

Values such as outdoor recreation, privacy, and protecting nature were of high importance and primary reasoning for improving wildlife habitats, water quality management, and trail maintenance. Respondents who value scenery were more likely to participate in improving wildlife habitats, while other respondents who valued privacy were more likely to participate in improving wildlife habitat and maintaining trails. There could be many reasons for this, but some research has found that in the southeast, reliance on land can play a big part in how that land is perceived. In a social survey study in 2004, it was found that landowners who depended on their property for their livelihood "were less likely to consider the aesthetic or intrinsic value of wildlife on their land than those who did not rely on their land for income" (Daley et al. 2004:216). Most Broad River stakeholders were less likely to participate in land management foreseen in the next five years. There could also be a discrepancy in evaluation of time. It might be easier for landowners to state with a yes or no if the scale of time was shorter such as two to three years instead of five. It can be hard to say what will happen to your land in the next 5 years when no one has thought that far ahead or unanticipated events occur. Surveying on a consistent basis of two to three years could be a better reflection of how stakeholder attitudes and values change over time.

Other studies using surveying or social science on larger scales have shown to be beneficial in the long-term integration of community research and/or monitoring efforts. For example, a study in 2012 found that municipalities across rural watersheds had limited to no communication outside of connection to Watershed Network sampling and determined that building a water management network was necessary to bridge communication between municipalities, farmers, and landowners (Rathwell & Peterson. 2012). In another study, Druschke (2012) highlights the quantitative relationship between interviewed farmers and landowner perspectives, and rhetorical language and landscape changes. Druschke argued that watersheds served as physical material and symbolism such as community for people, and found shifting dialogue from scientific to rhetorical language could help promote shared values and positively impact perspectives on soil and water management (Druschke 2012). In a 2016 survey, 275 landowners from Little River watershed, Texas responded and found that most landowner values were influenced by profitability, improving land for future family or heirs, and other personal values that influence best management practices. They acknowledge while respondents were interested in land management for profitability, personal values can influence how people most sustainably would obtain this profit (Dewald 2016). Each of these studies hold importance because they highlight the power of community perspective and values on the physical lands we manage.

Watershed Monitoring and Regulation

The majority of designated uses of streams within the Broad River watershed are for fishing. Stream designation plays an important part in how the state monitors streams. With designated uses such as drinking water, a stream is more heavily monitored on a consistent basis due to its importance in health to the community. Urban areas with high populations that use streams for drinking water are also more likely to be monitored on a consistent basis. Rural or agricultural communities rely on well water, stream water from small treatment plants, or purchased water from other counties for drinking use. Rural communities have limited monitoring resources, often leaving unresolved issues like agricultural run-off and septic leakage. Evidence has shown that Piedmont streams have been impacted by agricultural land use and that a main priority in improving watershed health for rural communities is through the reduction of non-point pollutants (Baker 1980; Fisher et al. 2000). With less watershed monitoring and higher levels of land management activities, local organizations and NGOs have stepped up to fill this monitoring gap but are limited by person-power and funding. The future of watershed monitoring is rooted in community participation such as citizen science, transparent research of local watershed groups, and funding provided by the state for these conservation efforts such as Georgia’s 319h grant. In 1998 a study found past agricultural land use had a long-term influence on streams and aquatic diversity and determined short-term solutions like improved riparian zones would not be able to counteract these long-tern effects (Harding et al. 1998). It should be considered that with state funding and environmental monitoring enforced by the community and local organizations more can be learned about how past land use influences stream health and develop sustainable monitoring plans in conjunction with the state and community for long-term conservation efforts.

CHAPTER 5

CONCLUSION

Protecting rivers and streams in rural landscapes depends on landowner's attitudes. NGOs like BRWA can help community members including landowners connect to resources and information about threats to clean water and healthy streams in their watershed. For NGOs to be effective in these objectives they need informative outreach tools and consistent data on watershed conditions. One outcome of the BRWA survey is that landowners are interested in the types of resources that would provide more information or training in water issues such as a website or informative pamphlet. This may be an area for BRWA to invest resources in the future that would enable more collaborative efforts within the community. Macroinvertebrate monitoring programs such as Adopt-A-Stream could be implemented to help increase engagement of local landowners in conservation activities (GDNR 2105). My results show that streams across the Broad River Watershed support diverse macroinvertebrate communities. Tracking changes in abundances of more sensitive taxa, such as EPTs, could provide information beyond the periodic monitoring done by the state. I would recommend focusing on macroinvertebrates in riffle and woody debris habitats. Streams that have more riffle habitat might be prioritized for safeguarding due to their ability to house more sensitive species. One resource created from this research is a GIS-based Story Map that encompasses the results of both studies and provides monitoring tools catering to landowners in the Broad River Watershed. Studies have emphasized the importance of public communication with tools that allow shared information throughout the watershed such as flood risk detection (Oubennaceur et al. 2021), stream health, agricultural management (Goodrich et al. 2020), and other watershed management.

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Appendix A. BRWA 2021 Adopt-A-Stream Report Raw Data & comments.

SampleSiteNumber	Site	River/Creek	Bridge or Culvert	AAS ID	Latitude	Longitude	Conductivity	Nitrate ppm	Nitrate Sampling	County Location
1	Deep Creek @Sand Hill Rd	Deep Creek	<Null>	5349	34.1236	-83.0214	<Null>	<Null>	Green	
2	Fork Creek @ Martin Road	Fork Creek	<Null>	5277	34.1812	-83.0096	<Null>	<Null>	Green	
3	Fork Creek @ Bowman Park	Fork Creek	<Null>	5276	34.1973	-83.0236	<Null>	<Null>	Green	
4	Fred Compton Branch @ 172	Scull Shoals Creek	<Null>	6881	34.1461	-83.1103	<Null>	<Null>	Red	
5	Mill Shoals @ Country Ridge Rd	Mill Shoal Creek	Country Ridge Drive	<Null>	34.258515	-83.095718	50	0.1	Yellow	
6	Mill Shoals @ Deerfield Ln	Mill Shoal Creek	Deerfield Circle North(a)	<Null>	34.267959	-83.102348	60	0.8	Red	
7	Mill Shoals @ Kinley Rd	Mill Shoal Creek	Deerfield Circle South (b)	<Null>	34.266061	-83.100127	40	0.6	Orange	
8	Mill Shoals @ next to Norman Dove Rd	Mill Shoal Creek	Pullian	<Null>	34.247783	-83.105697	105	2.8	Orange	
9	Site 9	Mill Shoal Creek	Sherman Dove Rd (d)	<Null>	34.241556	-83.095816	60	1.5	Yellow	
10	Site 10	Mill Shoal Creek	Rousy Duncan (North)	<Null>	34.238669	-83.094078	80	3	Yellow	
11	Site 11	Mill Shoal Creek	Rousy Duncan South (e)	<Null>	34.233422	-83.088948	85	2.5	Red	
12	Site 12	Mill Shoal Creek	Pullen Craddock	<Null>	34.23032	-83.105697	90	2.4	Orange	
13	Site 13	Mill Shoal Creek	Freedom Church & Pullen	<Null>	34.230351	-83.10675	60	0.9	Green	
14	Site 14	Mill Shoal Creek	Reed Brawner	<Null>	34.230394	-83.105547	73	1.5	Orange	
15	Site 15	Mill Shoal Creek	Abercombie	<Null>	34.216118	-83.096277	100	3.2	Orange	
16	Site 16	Mill Shoal Creek	Dove Drake	<Null>	34.207795	-83.104461	80	2.1	Orange	
17	Site 17	Mill Shoal Creek	Branch & Mill Shoal Church R	<Null>	34.215103	-83.1155	35	0.6	Yellow	
18	Site 18	Mill Shoal Creek	Parham Dudley	<Null>	34.196014	-83.101579	80	2.1	Green	
19	Site 19	Mill Shoal Creek	Bridge	<Null>	34.197105	-83.091705	70	1.6	Yellow	
20	Site 20	Butler Creek	Hoot Owl	<Null>	34.218331	-83.06107	70	1.75	Yellow	
21	Site 21	Butler Creek	Hendricks Ext/	<Null>	34.203303	-83.034706	60	1.25	Yellow	
22	Site 22	Butler Creek	Dusty Road	<Null>	34.188381	-83.06773	60	0.9	Green	
23	Site 23	Mill Shoal Creek	Brown Bridge	<Null>	34.169383	-83.068614	70	1.5	Orange	
24	Site 24	Mill Shoal Creek	King Hall Mill	<Null>	34.1589	-83.0657	70	1.35	Yellow	
25	Peyton Landing	Broad River		5298	34.1267	-83.0489				
26	Briar's Landing	Broad River		5275	34.074	-83.0043				
27	Trout Hole	Broad River		5157	33.9921	-82.6548				
28	Mill Shoals @ King Hall Mill Rd	Mill Shoal Creek		5298	34.1589	-83.0657				
29	Scull Shoals @ Homes Church Rd	Scull Shoals Creek		5349	34.1566	-83.1001				

Green	< 1ppm nitrates
Yellow	1.1-1.5 ppm nitrate
Orange	1.6 -2.5 ppm nitrates
Red	> 2.6 ppm nitrates

Note: AAS recommends that levels of nitrates greater than 1 ppm do not reflect a healthy stream
The UGA extension agent recommends testing well water twice a year if water is > 3 ppm and
putting in filtration system in if it is > 10 ppm.

Location	River	Year	AAS ID	n	Mean E. coli(cfu/ml	Mean Conductivity (	Nitrate ppm (c)
Trout Hole	Broad River	2021	5157	3	100	73	<1
Briars Landing	Broad River	2020	6680	3	66	63	<1
		2021		7	99 (a)	75	0.3
Peyton Ferry	Broad River	2020	5275	3	100	70	<1
		2021		3	111(a)	72.5	0.25
King Hall Mill	Mill Shoals Ck	2021	5298	7	344 (b-1)	80	1.5
David Homes Ch	Scull Shoals	2020	5350	3	277 (b-2)	53	<1
		2021		7	199 (a,b-2	60	0.8

a) Eliminated high count due to heavy rainfall (>0.9 in) the night before
b) Some counts > 400 cfu/ml. Which is considered be a level to avoid contact with water by SRK
c) Average of Hach test strips in 2020, and combination of spectrophotometer and strips in 2021
Note: Average is of samples taken on monthly basis. Mill Shoal Creek was sampled more often.

Summary: Although sampling on a routine basis has been prevented by the pandemic, the E coli counts are good in the Broad River proper, but fluccuate alot in the tributaries. Based on observations, the counts are mostly influenced by cattle having access to the streams, and perhaps chicken litter. Based on initial data, the higher nitrate levels are not usually associated with higher E coli levels, which seem to indicate that fields are being fertilized by stack house

Appendix B. 1 Stream Data including land use percentages

Stream	Subbasin	Health	County	Latitude	Longitude	Ag.per	Forest.per	Urban.per
Big Clouds Creek	South Broad	Impaired	Oglethorpe	33.958147	-83.166584	38	41	8
Carlan Creek	Hudson	Supporting	Franklin	34.307979	-83.33825	26	46	8
Clouds Creek	South Broad	Unknown	Oglethorpe	34.023528	-83.066703	34	46	8
Dove Creek	Broad	Impaired	Elbert	34.071328	-82.965562	6	67	12
Fork Creek	South Broad	Impaired	Madison	34.0656645	-83.0622721	45	34	11
Grove Creek	South Broad	Impaired	Oglethorpe	33.973928	-83.090985	18	59	8.5
Hanna Creek	Broad	Supporting	Madison	34.233796	-83.160755	32	47	11
Hickory Level Creek	Hudson	Supporting	Banks	34.307496	-83.543361	21	60	7.5
Mill Shoal Creek	South Broad	Impaired	Madison	34.023283	-83.209428	39	29	26
Nails Creek	Hudson	Supporting	Franklin	34.352222	-83.362458	33	44	8
Shiloh Creek	Broad	Unknown	Madison	34.220543	-83.176826	44	36	13
Stephen Creek	Middle Broad	Unknown	Franklin	34.349035	-83.229677	43	30	16
Sulpur Springs Creek	South Broad	Supporting	Madison	34.00546	-83.271866	19	53	22
Tom's Creek	North Broad	Unknown	Franklin	34.463167	-83.224709	25	50	12
Unawatti Creek	North Broad	Unknown	Franklin	34.376132	-83.165883	43	31	17

Appendix B.2 Stream Macroinvertebrate Data by Stream

Stream	Habitat	Family	Taxon	EPT	Number	Tolerance	Include
Big Clouds Creek	Woody Debris	Hydrachnidae	Acari	0	1	8	0
Shiloh Creek	Sandy/Silt	Hydrachnidae	Acari	0	7	8	0
Unawatti Creek	Sandy/Silt	Hydrachnidae	Acari	0	2	8	0
Big Clouds Creek	Sandy/Silt	Corbiculidae	Corbicula	0	1	6.3	1
Big Clouds Creek	Woody Debris	Capniidae	Larvae	1	3	1	1
Big Clouds Creek	Sandy/Silt	Capniidae	Larvae	1	10	1	1
Big Clouds Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	5	6.65	1
Big Clouds Creek	Woody Debris	Chironomidae	Larvae	0	5	5.79	1
Clouds Creek	Riffle	Chironomidae	Adult	0	2	NA	0
Grove Creek	Sandy/Silt	Chironomidae	Adult	0	1	NA	0
Hickory Level Creek	Sandy/Silt	Chironomidae	Adult	0	1	NA	0
Nails Creek	Woody Debris	Chironomidae	Adult	0	3	NA	0
Shiloh Creek	Sandy/Silt	Chironomidae	Adult	0	2	NA	0
Stephen Creek	Sandy/Silt	Chironomidae	Adult	0	3	NA	0
Stephen Creek	Woody Debris	Chironomidae	Adult	0	1	NA	0
Stephen Creek	Riffle	Chironomidae	Adult	0	5	NA	0

Sulphur Springs	Sandy/Silt	Chironomidae	Adult	0	1	NA	0
Sulphur Springs	Riffle	Chironomidae	Adult	0	1	NA	0
Tom's Creek	Sandy/Silt	Chironomidae	Adult	0	1	NA	0
Unawatti Creek	Sandy/Silt	Chironomidae	Adult	0	2	NA	0
Big Clouds Creek	Sandy/Silt	Chironomidae	Larvae	0	16	5.79	1
Mill Shoals Creek	Riffle	Elmidae	Adult	0	2	2.7	1
Unawatti Creek	Sandy/Silt	Elmidae	Adult	0	1	3.58	1
Unawatti Creek	Riffle	Elmidae	Adult	0	2	3.58	1
Mill Shoals Creek	Sandy/Silt	Hydraenidae	Adult	0	2	5	1
Tom's Creek	Riffle	Perlidae	Adult	1	1	1	1
Big Clouds Creek	Woody Debris	Heptageniidae	Larvae	1	15	2.25	1
Big Clouds Creek	Sandy/Silt	Heptageniidae	Larvae	1	5	2.25	1
Big Clouds Creek	Sandy/Silt	Tipulidae	Larvae	0	4	5.83	1
Big Clouds Creek	Sandy/Silt	Oligochaeta	NA	0	6	8.27	1
Hanna Creek	Woody Debris	Elmidae	Ancyronyx	0	2	6.9	1
Big Clouds Creek	Sandy/Silt	Gomphidae	Progomphus	0	3	8.7	1
Carlan Creek	Sandy/Silt	Dryopidae	Adult	0	1	5.4	1

Carlan Creek	Woody Debris	Cambaridae	Cambarinae	0	1	6	1
Carlan Creek	Woody Debris	Gomphidae	Gomphus	0	2	5.47	1
Hanna Creek	Sandy/Silt	Formicidae	Ants	0	1	NA	0
Carlan Creek	Woody Debris	Ephemeridae	Hexagenia	1	1	2.2	1
Carlan Creek	Woody Debris	Baetidae	Larvae	1	6	4	1
Stephen Creek	Riffle	Formicidae	Ants	0	1	0	0
Unawatti Creek	Sandy/Silt	Formicidae	Ants	0	1	NA	0
Carlan Creek	Sandy/Silt	Aphididae	Aphids	0	1	NA	0
Clouds Creek	Riffle	Aphididae	Aphids	0	10	NA	0
Clouds Creek	Woody Debris	Aphididae	Aphids	0	1	NA	0
Mill Shoals Creek	Riffle	Aphididae	Aphids	0	1	NA	0
Nails Creek	Sandy/Silt	Aphididae	Aphids	0	4	NA	0
Stephen Creek	Sandy/Silt	Aphididae	Aphids	0	1	NA	0
Stephen Creek	Riffle	Aphididae	Aphids	0	4	NA	0
Sulphur Springs	Sandy/Silt	Aphididae	Aphids	0	1	NA	0
Tom's Creek	Riffle	Aphididae	Aphids	0	8	NA	0
Tom's Creek	Woody Debris	Aphididae	Aphids	0	5	NA	0
Clouds Creek	Sandy/Silt	Araneae	Araneae	0	1	NA	0
Carlan Creek	Woody Debris	Chironomidae	Larvae	0	18	5.79	1

Mill Shoals Creek	Riffle	Araneae	Araneae	0	1	NA	0
Carlan Creek	Sandy/Silt	Chironomidae	Larvae	0	6	5.79	1
Carlan Creek	Woody Debris	Elmidae	Larvae	0	1	3.58	1
Carlan Creek	Woody Debris	Heptageniidae	Larvae	1	12	2.25	1
Carlan Creek	Sandy/Silt	Heptageniidae	Larvae	1	4	2.25	1
Sulphur Springs	Sandy/Silt	Baetiscidae	Baetisca	1	5	4	1
Carlan Creek	Woody Debris	Hydropsychidae	Larvae	1	3	4	1
Sulphur Springs	Woody Debris	Baetiscidae	Baetisca	1	1	1.87	1
Unawatti Creek	Sandy/Silt	Baetiscidae	Baetisca	1	1	1.87	1
Carlan Creek	Woody Debris	Leptophlebiidae	Larvae	1	12	2.53	1
Carlan Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	8	2.53	1
Carlan Creek	Woody Debris	Leuctridae	Larvae	1	1	0.7	1
Carlan Creek	Woody Debris	Limnephilidae	Larvae	1	2	4	1
Carlan Creek	Woody Debris	Perlodidae	Larvae	1	1	2	1
Carlan Creek	Woody Debris	Tipulidae	Larvae	0	5	5.83	1
Carlan Creek	Sandy/Silt	Tipulidae	Larvae	0	5	5.83	1
Carlan Creek	Woody Debris	Gomphidae	Progomphus	0	1	8.7	1
Carlan Creek	Sandy/Silt	Gomphidae	Progomphus	0	1	8.7	1
Clouds Creek	Riffle	Perlidae	Agnetina	1	1	0	1
Clouds Creek	Riffle	Hydropsychidae	Cheumatopsyche	1	4	6.6	1

Fork Creek	Sandy/Silt	NA	Caterpillar	0	1	NA	0
Clouds Creek	Riffle	Corbiculidae	Corbicula	0	2	6.3	1
Clouds Creek	Sandy/Silt	Corbiculidae	Corbicula	0	34	6.3	1
Nails Creek	Woody Debris	Hydropsychidae	Cheumatopysche	1	1	6.6	1
Grove Creek	Woody Debris	Philopotamidae	Chimarra	1	1	3	1
Dove Creek	Riffle	Poduridae	Collembola	0	1	NA	0
Shiloh Creek	Sandy/Silt	Poduridae	Collembola	0	1	NA	0
Clouds Creek	Riffle	Corydalidae	Corydalus	0	1	5.6	1
Stephen Creek	Riffle	Poduridae	Collembola	0	18	NA	0
Tom's Creek	Riffle	Poduridae	Collembola	0	2	NA	0
Tom's Creek	Sandy/Silt	Poduridae	Collembola	0	2	NA	0
Tom's Creek	Woody Debris	Poduridae	Collembola	0	2	NA	0
Unawatti Creek	Sandy/Silt	Poduridae	Collembola	0	27	NA	0
Unawatti Creek	Riffle	Poduridae	Collembola	0	10	NA	0
Unawatti Creek	Woody Debris	Poduridae	Collembola	0	6	NA	0
Big Clouds Creek	Sandy/Silt	Poduridae	Collembola	0	2	NA	0
Hanna Creek	Woody Debris	Poduridae	Collembola	0	8	NA	0
Hickory Level Creek	Sandy/Silt	Poduridae	Collembola	0	1	NA	0
Nails Creek	Sandy/Silt	Poduridae	Collembola	0	2	NA	0

Big Clouds Creek	Woody Debris	Corbiculidae	Corbicula	0	1	6.3	1
Clouds Creek	Riffle	Baetidae	Larvae	1	30	4	1
Clouds Creek	Sandy/Silt	Baetidae	Larvae	1	4	4	1
Clouds Creek	Riffle	Capniidae	Larvae	1	12	1	1
Clouds Creek	Woody Debris	Corbiculidae	Corbicula	0	1	6.3	1
Dove Creek	Woody Debris	Corbiculidae	Corbicula	0	2	6.3	1
Dove Creek	Sandy/Silt	Corbiculidae	Corbicula	0	8	6.3	1
Clouds Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	29	6.65	1
Clouds Creek	Riffle	Chironomidae	Larvae	0	53	5.79	1
Clouds Creek	Sandy/Silt	Chironomidae	Larvae	0	44	5.79	1
Clouds Creek	Woody Debris	Chironomidae	Larvae	0	7	5.79	1
Clouds Creek	Sandy/Silt	Chloroperlidae	Larvae	1	3	0.68	1
Clouds Creek	Woody Debris	Elmidae	Larvae	0	5	3.58	1
Clouds Creek	Riffle	Heptageniidae	Larvae	1	24	2.25	1
Clouds Creek	Woody Debris	Heptageniidae	Larvae	1	2	2.25	1
Clouds Creek	Riffle	Hydropsychidae	Larvae	1	24	4	1
Shiloh Creek	Sandy/Silt	Corbiculidae	Corbicula	0	23	6.3	1
Clouds Creek	Sandy/Silt	Pteronarcyidae	Larvae	1	1	1.75	1
Clouds Creek	Riffle	Simuliidae	Larvae	0	45	5.07	1
Clouds Creek	Sandy/Silt	Macromiidae	Macromia	0	1	6.7	1

Clouds Creek	Riffle	Oligochaeta	NA	0	15	8.27	1
Clouds Creek	Sandy/Silt	Oligochaeta	NA	0	13	8.27	1
Clouds Creek	Woody Debris	Pleuroceridae	NA	0	3	2.05	1
Clouds Creek	Riffle	Chironomidae	Pupae	0	6	NA	0
Clouds Creek	Sandy/Silt	Chironomidae	Pupae	0	16	NA	0
Dove Creek	Riffle	Tipulidae	Antocha	0	1	4.6	1
Dove Creek	Riffle	Corbiculidae	Corbicula	0	17	6.3	1
Dove Creek	Riffle	Baetidae	Larvae	1	2	4	1
Dove Creek	Sandy/Silt	Capniidae	Larvae	1	2	1	1
Mill Shoals Creek	Sandy/Silt	NA	Eggs	0	3	NA	0
Shiloh Creek	Riffle	Ephemerellidae	Ephemerella	1	22	1.66	1
Dove Creek	Woody Debris	Chironomidae	Larvae	0	17	5.79	1
Dove Creek	Riffle	Chironomidae	Larvae	0	4	5.79	1
Dove Creek	Riffle	Ephemerellidae	Larvae	1	12	1.63	1
Sulphur Springs	Sandy/Silt	Gomphidae	Hagenius	0	1	4	1
Dove Creek	Woody Debris	Copepods	Harpacticoda	0	2	8	1
Fork Creek	Sandy/Silt	Copepods	Harpacticoda	0	1	8	1
Shiloh Creek	Riffle	Copepods	Harpacticoda	0	3	8	1
Dove Creek	Woody Debris	Heptageniidae	Larvae	1	3	2.25	1
Dove Creek	Woody Debris	Leptophlebiidae	Larvae	1	12	2.53	1

Dove Creek	Riffle	Leptophlebiidae	Larvae	1	2	2.53	1
Dove Creek	Sandy/Silt	Leuctridae	Larvae	1	1	0.7	1
Dove Creek	Riffle	Nemouridae	Larvae	1	14	3.27	1
Dove Creek	Riffle	Simuliidae	Larvae	0	2	5.07	1
Dove Creek	Riffle	Taeniopterygidae	Larvae	1	2	4	1
Dove Creek	Riffle	Tipulidae	Larvae	0	6	5.83	1
Fork Creek	Sandy/Silt	Capniidae	Adult	1	1	1	1
Fork Creek	Woody Debris	Cambaridae	Cambarinae	0	2	6	1
Fork Creek	Woody Debris	Corbiculidae	Corbicula	0	1	6.3	1
Fork Creek	Sandy/Silt	Corbiculidae	Corbicula	0	15	6.3	1
Big Clouds Creek	Sandy/Silt	Baetidae	Larvae	1	1	4	1
Fork Creek	Sandy/Silt	Baetidae	Larvae	1	1	4	1
Fork Creek	Woody Debris	Capniidae	Larvae	1	7	1	1
Fork Creek	Sandy/Silt	Capniidae	Larvae	1	2	1	1
Fork Creek	Woody Debris	Chironomidae	Larvae	0	44	5.79	1
Fork Creek	Woody Debris	Baetidae	Larvae	1	1	4	1
Fork Creek	Sandy/Silt	Chironomidae	Larvae	0	71	5.79	1
Hanna Creek	Riffle	Baetidae	Larvae	1	1	4	1
Fork Creek	Woody Debris	Elmidae	Larvae	0	4	3.58	1
Fork Creek	Sandy/Silt	Ephemerellidae	Larvae	1	13	1.63	1

Nails Creek	Sandy/Silt	Baetidae	Larvae	1	1	4	1
Fork Creek	Woody Debris	Ephemeridae	Larvae	1	2	4.7	1
Shiloh Creek	Riffle	Baetidae	Larvae	1	2	4	1
Fork Creek	Woody Debris	Heptageniidae	Larvae	1	23	2.25	1
Fork Creek	Sandy/Silt	Heptageniidae	Larvae	1	6	2.25	1
Fork Creek	Woody Debris	Hydropsychidae	Larvae	1	1	4	1
Tom's Creek	Riffle	Baetidae	Larvae	1	1	4	1
Fork Creek	Woody Debris	Leptophlebiidae	Larvae	1	10	2.53	1
Fork Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	5	2.53	1
Fork Creek	Sandy/Silt	Leuctridae	Larvae	1	1	0.7	1
Fork Creek	Woody Debris	Perlodidae	Larvae	1	4	2	1
Fork Creek	Sandy/Silt	Perlodidae	Larvae	1	1	2	1
Fork Creek	Woody Debris	Taeniopterygidae	Larvae	1	1	4	1
Carlan Creek	Sandy/Silt	Capniidae	Larvae	1	1	1	1
Fork Creek	Sandy/Silt	Taeniopterygidae	Larvae	1	1	4	1
Fork Creek	Woody Debris	Tipulidae	Larvae	0	1	4.7	1
Fork Creek	Sandy/Silt	Tipulidae	Larvae	0	1	4.7	1
Fork Creek	Woody Debris	Lepidostomatidae	Lepidostoma	1	1	1	1
Fork Creek	Woody Debris	Oligochaeta	NA	0	5	8.27	1
Fork Creek	Sandy/Silt	Oligochaeta	NA	0	33	8.27	1

Stephen Creek	Sandy/Silt	Capniidae	Larvae	1	1	1	1
Fork Creek	Sandy/Silt	Gomphidae	Progomphus	0	3	8.7	1
Fork Creek	Sandy/Silt	NA	Pupae	0	4	NA	0
Grove Creek	Sandy/Silt	Corbiculidae	Corbicula	0	11	6.3	1
Grove Creek	Woody Debris	Corbiculidae	Corbicula	0	10	6.3	1
Grove Creek	Woody Debris	Cambaridae	Crayfish	0	2	6	1
Carlan Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	2	6.65	1
Clouds Creek	Riffle	Ceratopogonidae	Larvae	0	4	6.65	1
Grove Creek	Woody Debris	Gomphidae	Gomphus	0	1	5.47	1
Dove Creek	Woody Debris	Ceratopogonidae	Larvae	0	1	6.65	1
Fork Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	7	6.65	1
Grove Creek	Woody Debris	Ephemeridae	Hexagenia	1	2	2.2	1
Grove Creek	Sandy/Silt	Gomphidae	Lanthus	0	1	2.7	1
Shiloh Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	1	6.65	1
Stephen Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	7	6.65	1
Stephen Creek	Woody Debris	Ceratopogonidae	Larvae	0	1	6.65	1
Stephen Creek	Riffle	Ceratopogonidae	Larvae	0	4	6.65	1
Sulphur Springs	Sandy/Silt	Ceratopogonidae	Larvae	0	5	6.65	1
Grove Creek	Sandy/Silt	Capniidae	Larvae	1	4	1	1
Grove Creek	Woody Debris	Capniidae	Larvae	1	5	1	1

Tom's Creek	Woody Debris	Ceratopogonidae	Larvae	0	2	6.65	1
Unawatti Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	10	6.65	1
Unawatti Creek	Woody Debris	Ceratopogonidae	Larvae	0	1	6.65	1
Grove Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	5	6.65	1
Grove Creek	Sandy/Silt	Chironomidae	Larvae	0	67	5.79	1
Grove Creek	Woody Debris	Chironomidae	Larvae	0	81	5.79	1
Grove Creek	Woody Debris	Heptageniidae	Larvae	1	8	2.25	1
Grove Creek	Woody Debris	Hydropsychidae	Larvae	1	5	4	1
Grove Creek	Woody Debris	Leptophlebiidae	Larvae	1	10	2.53	1
Grove Creek	Sandy/Silt	NA	Larvae	1	10	NA	1
Grove Creek	Woody Debris	Siphlonuridae	Larvae	1	2	2.6	1
Dove Creek	Sandy/Silt	Chironomidae	Larvae	0	27	5.79	1
Grove Creek	Sandy/Silt	Oligochaeta	NA	0	8	8.27	1
Grove Creek	Woody Debris	Oligochaeta	NA	0	20	8.27	1
Grove Creek	Sandy/Silt	Gomphidae	Progomphus	0	4	8.7	1
Grove Creek	Woody Debris	Gomphidae	Progomphus	0	1	8.7	1
Hanna Creek	Riffle	Perlidae	Acroneuria	1	4	1.6	1
Hanna Creek	Riffle	Tipulidae	Antocha	0	1	4.6	1
Hanna Creek	Riffle	Formicidae	Ants	0	2	NA	0
Hanna Creek	Riffle	Athericidae	Atherix	0	2	2.1	1

Hanna Creek	Riffle	Calopterygidae	Calopteryx	0	1	8.3	1
Hanna Creek	Riffle	Corbiculidae	Corbicula	0	3	6.3	1
Hanna Creek	Sandy/Silt	Corbiculidae	Corbicula	0	13	6.3	1
Hanna Creek	Riffle	Corydalidae	Corydalus	0	1	5.6	1
Hanna Creek	Riffle	Isonychiidae	Isonychia	1	1	3.8	1
Hanna Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	15	6.65	1
Hanna Creek	Riffle	Chironomidae	Larvae	0	7	5.79	1
Hanna Creek	Sandy/Silt	Chironomidae	Larvae	0	6	5.79	1
Hanna Creek	Riffle	Ephemerellidae	Larvae	1	1	1.63	1
Hanna Creek	Riffle	Heptageniidae	Larvae	1	7	2.25	1
Hanna Creek	Sandy/Silt	Heptageniidae	Larvae	1	3	2.25	1
Hanna Creek	Riffle	Hydropsychidae	Larvae	1	12	4	1
Hanna Creek	Sandy/Silt	Lepidostomatidae	Lepidostoma	1	1	1	1
Hanna Creek	Riffle	Oligochaeta	NA	0	1	8.27	1
Hanna Creek	Woody Debris	Perlidae	Acroneuria	1	2	1.6	1
Hanna Creek	Woody Debris	Formicidae	Ants	0	3	NA	0
Hanna Creek	Woody Debris	Aeshnidae	Boyeria	0	1	6.3	1
Hanna Creek	Woody Debris	Calopterygidae	Calopteryx	0	3	8.3	1
Hanna Creek	Woody Debris	Cambaridae	Cambarinae	0	2	6	1
Hanna Creek	Woody Debris	Baetidae	Larvae	1	4	4	1

Hanna Creek	Woody Debris	Chironomidae	Larvae	0	90	5.79	1
Hanna Creek	Woody Debris	Elmidae	Larvae	0	9	3.58	1
Shiloh Creek	Riffle	Chloroperlidae	Larvae	1	2	0.68	1
Hanna Creek	Woody Debris	Gomphidae	Larvae	0	3	5.47	1
Mill Shoals Creek	Woody Debris	Coenagrionidae	Larvae	0	1	9	1
Unawatti Creek	Woody Debris	Coenagrionidae	Larvae	0	1	9	1
Hanna Creek	Woody Debris	Heptageniidae	Larvae	1	19	2.25	1
Clouds Creek	Riffle	Elmidae	Larvae	0	1	3.58	1
Hanna Creek	Woody Debris	Hydropsychidae	Larvae	1	38	4	1
Hanna Creek	Woody Debris	Tipulidae	Larvae	0	2	5.83	NA
Fork Creek	Sandy/Silt	Elmidae	Larvae	0	2	3.58	1
Hanna Creek	Sandy/Silt	Elmidae	Larvae	0	3	3.58	1
Hanna Creek	Woody Debris	Lepidostomatidae	Lepidostoma	1	1	1	1
Hanna Creek	Woody Debris	Macromiidae	Macromia	0	2	6.7	1
Mill Shoals Creek	Sandy/Silt	Elmidae	Larvae	0	1	3.58	1
Nails Creek	Sandy/Silt	Elmidae	Larvae	0	1	3.58	1
Hanna Creek	Woody Debris	Oligochaeta	NA	0	4	8.27	1
Shiloh Creek	Sandy/Silt	Elmidae	Larvae	0	1	3.58	1
Hanna Creek	Woody Debris	Gomphidae	Progomphus	0	1	8.7	1

Sulphur Springs	Riffle	Elmidae	Larvae	0	2	3.58	1
Hanna Creek	Woody Debris	Peltoperlidae	Tallaperla	1	5	1.4	1
Unawatti Creek	Sandy/Silt	Elmidae	Larvae	0	1	3.58	1
Unawatti Creek	Riffle	Elmidae	Larvae	0	1	3.58	1
Hickory Level Creek	Sandy/Silt	Araneae	Araneae	0	4	NA	0
Dove Creek	Riffle	Empididae	Larvae	0	3	8.1	1
Hanna Creek	Woody Debris	Empididae	Larvae	0	1	8.1	1
Shiloh Creek	Riffle	Empididae	Larvae	0	1	8.1	1
Stephen Creek	Riffle	Empididae	Larvae	0	1	8.1	1
Tom's Creek	Riffle	Empididae	Larvae	0	1	8.1	1
Big Clouds Creek	Sandy/Silt	Ephemerellidae	Larvae	1	1	1.63	1
Dove Creek	Woody Debris	Ephemerellidae	Larvae	1	1	1.63	1
Dove Creek	Sandy/Silt	Ephemerellidae	Larvae	1	1	1.63	1
Hickory Level Creek	Woody Debris	Aeshnidae	Boyeria	0	1	6.3	1
Hickory Level Creek	Sandy/Silt	Ephemeridae	Hexagenia	1	3	4.7	1
Grove Creek	Sandy/Silt	Ephemerellidae	Larvae	1	1	1.63	1
Hickory Level Creek	Woody Debris	Chironomidae	Larvae	0	14	5.79	1
Hickory Level Creek	Sandy/Silt	Chironomidae	Larvae	0	75	5.79	1

Hickory Level Creek	Sandy/Silt	Ephemerellidae	Larvae	1	1	1.63	1
Shiloh Creek	Sandy/Silt	Ephemerellidae	Larvae	1	5	1.63	1
Tom's Creek	Riffle	Ephemerellidae	Larvae	1	2	1.63	1
Big Clouds Creek	Woody Debris	Ephemeridae	Larvae	1	1	2.2	1
Hickory Level Creek	Woody Debris	Ephemerellidae	Larvae	1	2	1.63	1
Fork Creek	Sandy/Silt	Ephemeridae	Larvae	1	1	4.7	1
Hanna Creek	Woody Debris	Ephemeridae	Larvae	1	1	2.2	1
Hanna Creek	Sandy/Silt	Gomphidae	Larvae	0	2	5.47	1
Hickory Level Creek	Woody Debris	Hydropsychidae	Larvae	1	11	4	1
Hickory Level Creek	Sandy/Silt	Hydropsychidae	Larvae	1	3	4	1
Tom's Creek	Riffle	Gomphidae	Larvae	0	1	5.47	1
Hickory Level Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	9	2.53	1
Hickory Level Creek	Sandy/Silt	Perlodidae	Larvae	1	1	2	1
Hickory Level Creek	Woody Debris	Taeniopterygidae	Larvae	1	1	4	1
Hickory Level Creek	Woody Debris	Tipulidae	Larvae	0	1	5.83	1
Hickory Level Creek	Sandy/Silt	Oligochaeta	NA	0	4	8.27	1

Clouds Creek	Sandy/Silt	Heptageniidae	Larvae	1	7	2.25	1
Hickory Level Creek	Sandy/Silt	Chironomidae	Pupae	0	11	NA	0
Hickory Level Creek	Woody Debris	Heptageniidae	Stenonema	1	8	7.5	1
Hickory Level Creek	Sandy/Silt	Heptageniidae	Stenonema	1	2	7.5	1
Mill Shoals Creek	Riffle	Perlidae	Acroneuria	1	1	1.6	1
Grove Creek	Sandy/Silt	Heptageniidae	Larvae	1	1	2.25	1
Mill Shoals Creek	Woody Debris	Formicidae	Ants	0	1	NA	0
Mill Shoals Creek	Sandy/Silt	Ephemeridae	Hexagenia	1	1	4.7	1
Mill Shoals Creek	Riffle	Baetidae	Larvae	1	1	4	1
Mill Shoals Creek	Woody Debris	Chironomidae	Larvae	0	2	5.79	1
Mill Shoals Creek	Sandy/Silt	Chironomidae	Larvae	0	3	5.79	1
Mill Shoals Creek	Riffle	Chironomidae	Larvae	0	5	5.79	1
Mill Shoals Creek	Woody Debris	Elmidae	Larvae	0	1	3.58	1
Mill Shoals Creek	Woody Debris	Heptageniidae	Larvae	1	3	2.25	1
Stephen Creek	Riffle	Heptageniidae	Larvae	1	3	2.25	1

Mill Shoals Creek	Sandy/Silt	Heptageniidae	Larvae	1	7	2.25	1
Mill Shoals Creek	Riffle	Heptageniidae	Larvae	1	4	2.25	1
Mill Shoals Creek	Woody Debris	Hydropsychidae	Larvae	1	4	4	1
Tom's Creek	Riffle	Heptageniidae	Larvae	1	1	2.25	1
Tom's Creek	Sandy/Silt	Heptageniidae	Larvae	1	2	2.25	1
Mill Shoals Creek	Sandy/Silt	Hydropsychidae	Larvae	1	1	4	1
Mill Shoals Creek	Riffle	Hydropsychidae	Larvae	1	2	4	1
Mill Shoals Creek	Woody Debris	NA	Larvae	1	1	NA	1
Mill Shoals Creek	Woody Debris	Perlidae	Larvae	1	2	1	1
Clouds Creek	Woody Debris	Hydropsychidae	Larvae	1	1	4	1
Dove Creek	Riffle	Hydropsychidae	Larvae	1	2	4	1
Mill Shoals Creek	Riffle	Philopotamidae	Larvae	1	2	3	1
Grove Creek	Sandy/Silt	Hydropsychidae	Larvae	1	1	4	1
Mill Shoals Creek	Woody Debris	Polycentropodidae	Larvae	1	1	4.07	1
Mill Shoals Creek	Riffle	Tipulidae	Larvae	0	1	4.7	1
Mill Shoals Creek	Sandy/Silt	Oligochaeta	NA	0	4	8.27	1

Mill Shoals Creek	Riffle	Oligochaeta	NA	0	2	8.27	1
Mill Shoals Creek	Sandy/Silt	Gomphidae	Progomphus	0	2	8.7	1
Mill Shoals Creek	Sandy/Silt	NA	Pupae	0	2	NA	0
Mill Shoals Creek	Riffle	Elmidae	Stenelmis	0	5	5.4	1
Nails Creek	Sandy/Silt	Corbiculidae	Corbicula	0	8	6.3	1
Shiloh Creek	Riffle	Hydropsychidae	Larvae	1	14	4	1
Stephen Creek	Sandy/Silt	Hydropsychidae	Larvae	1	1	4	1
Nails Creek	Woody Debris	Baetidae	Larvae	1	6	4	1
Nails Creek	Sandy/Silt	Chironomidae	Larvae	0	14	5.79	1
Nails Creek	Woody Debris	Chironomidae	Larvae	0	24	5.79	1
Nails Creek	Woody Debris	Elmidae	Larvae	0	1	3.58	1
Nails Creek	Woody Debris	Tipulidae	Larvae	0	1	5.83	1
Nails Creek	Sandy/Silt	Oligochaeta	NA	0	5	8.27	1
Nails Creek	Woody Debris	Oligochaeta	NA	0	31	8.27	1
Shiloh Creek	Riffle	Baetiscidae	Baetisca	1	3	1.87	1
Shiloh Creek	Riffle	Hydropsychidae	Cheumatopsyche	1	2	6.6	1
Shiloh Creek	Sandy/Silt	Hydroptilidae	Larvae	1	1	5.9	1
Stephen Creek	Riffle	Hydroptilidae	Larvae	1	1	5.9	1
Tom's Creek	Riffle	Hydroptilidae	Larvae	1	2	5.9	1

Clouds Creek	Riffle	Leptoceridae	Larvae	1	1	3.47	1
Clouds Creek	Sandy/Silt	Leptoceridae	Larvae	1	1	3.47	1
Hanna Creek	Woody Debris	Leptoceridae	Larvae	1	2	3.47	1
Sulphur Springs	Woody Debris	Leptoceridae	Larvae	1	2	3.47	1
Tom's Creek	Woody Debris	Leptoceridae	Larvae	1	1	3.47	1
Big Clouds Creek	Woody Debris	Leptophlebiidae	Larvae	1	1	2.53	1
Big Clouds Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	1	2.53	1
Shiloh Creek	Riffle	Corbiculidae	Corbicula	0	25	6.3	1
Shiloh Creek	Riffle	Psephenidae	Ectopria	0	1	4.3	1
Shiloh Creek	Riffle	Chironomidae	Larvae	0	112	5.79	1
Shiloh Creek	Riffle	Leuctridae	Larvae	1	1	0.7	1
Shiloh Creek	Riffle	Tipulidae	Larvae	0	5	5.83	1
Shiloh Creek	Riffle	Macromiidae	Macromia	0	1	6.7	1
Shiloh Creek	Riffle	Heptageniidae	Stenonema	1	11	7.5	1
Shiloh Creek	Sandy/Silt	Tipulidae	Antocha	0	1	4.6	1
Nails Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	3	2.53	1
Tom's Creek	Sandy/Silt	Leptophlebiidae	Larvae	1	1	2.53	1
Shiloh Creek	Sandy/Silt	Araneae	Araneae	0	2	NA	0
Shiloh Creek	Sandy/Silt	Baetiscidae	Baetisca	1	6	1.87	1

Dove Creek	Riffle	Leuctridae	Larvae	1	2	0.7	1
Shiloh Creek	Sandy/Silt	Tipulidae	Dicranota	0	16	0	1
Shiloh Creek	Sandy/Silt	Gomphidae	Hagenius	0	2	4	1
Shiloh Creek	Sandy/Silt	Tipulidae	Hexatoma	0	2	4.7	1
Shiloh Creek	Sandy/Silt	Chironomidae	Larvae	0	84	5.79	1
Shiloh Creek	Sandy/Silt	Leuctridae	Larvae	1	5	0.7	1
Clouds Creek	Woody Debris	Limnephilidae	Larvae	1	1	4	1
Carlan Creek	Sandy/Silt	NA	Larvae	1	1	NA	0
Dove Creek	Riffle	NA	Larvae	1	1	NA	1
Fork Creek	Sandy/Silt	NA	Larvae	1	3	NA	1
Shiloh Creek	Sandy/Silt	Oligochaeta	NA	0	3	8.27	1
Grove Creek	Sandy/Silt	NA	Larvae	1	2	NA	1
Shiloh Creek	Sandy/Silt	Gomphidae	Progomphus	0	4	8.7	1
Shiloh Creek	Sandy/Silt	NA	Larvae	1	1	NA	1
Stephen Creek	Riffle	NA	Larvae	1	3	NA	1
Sulphur Springs	Riffle	NA	Larvae	1	1	NA	1
Tom's Creek	Riffle	NA	Larvae	1	2	NA	1
Shiloh Creek	Sandy/Silt	Chironomidae	Tanypodinae	0	2	6.7	1
Stephen Creek	Woody Debris	Perlidae	Agnetina	1	2	0	1
Unawatti Creek	Sandy/Silt	NA	Larvae	0	1	NA	1

Dove Creek	Sandy/Silt	Nemouridae	Larvae	1	1	3.27	1
Stephen Creek	Sandy/Silt	Amphipod	Amphipod	0	1	8	1
Tom's Creek	Riffle	Nemouridae	Larvae	1	2	3.27	1
Stephen Creek	Riffle	Amphipod	Amphipod	0	1	8	1
Dove Creek	Woody Debris	Perlidae	Larvae	1	0	1	1
Stephen Creek	Sandy/Silt	Poduridae	Collembola	0	21	NA	0
Tom's Creek	Riffle	Perlidae	Larvae	1	1	1	1
Stephen Creek	Sandy/Silt	Corbiculidae	Corbicula	0	39	6.3	1
Clouds Creek	Riffle	Perlodidae	Larvae	1	4	2	1
Clouds Creek	Sandy/Silt	Perlodidae	Larvae	1	2	2	1
Stephen Creek	Riffle	Corbiculidae	Corbicula	0	26	6.3	1
Stephen Creek	Sandy/Silt	Ephemeridae	Hexagenia	1	1	2.2	1
Hickory Level Creek	Woody Debris	Perlodidae	Larvae	1	4	2	1
Stephen Creek	Riffle	Gomphidae	Lanthus	0	2	2.7	1
Stephen Creek	Woody Debris	Baetidae	Larvae	1	18	4	1
Sulphur Springs	Riffle	Philopotamidae	Larvae	1	1	3	1
Unawatti Creek	Riffle	Philopotamidae	Larvae	1	1	3	1
Stephen Creek	Sandy/Silt	Physidae	Larvae	0	1	9.1	1
Stephen Creek	Riffle	Baetidae	Larvae	1	28	4	1
Shiloh Creek	Riffle	Polycentropodidae	Larvae	1	1	4.07	1

Stephen Creek	Woody Debris	Capniidae	Larvae	1	2	1	1
Stephen Creek	Sandy/Silt	Chironomidae	Larvae	0	89	5.79	1
Clouds Creek	Sandy/Silt	Simuliidae	Larvae	0	8	5.07	1
Stephen Creek	Woody Debris	Chironomidae	Larvae	0	2	5.79	1
Hanna Creek	Riffle	Simuliidae	Larvae	0	1	5.07	1
Hickory Level Creek	Woody Debris	Simuliidae	Larvae	0	1	5.07	1
Shiloh Creek	Riffle	Simuliidae	Larvae	0	1	5.07	1
Shiloh Creek	Sandy/Silt	Simuliidae	Larvae	0	1	5.07	1
Stephen Creek	Sandy/Silt	Simuliidae	Larvae	0	1	5.07	1
Stephen Creek	Riffle	Chironomidae	Larvae	0	150	5.79	1
Stephen Creek	Sandy/Silt	Elmidae	Larvae	0	1	3.58	1
Stephen Creek	Woody Debris	Heptageniidae	Larvae	1	22	2.25	1
Stephen Creek	Woody Debris	Hydropsychidae	Larvae	1	12	4	1
Stephen Creek	Riffle	Hydropsychidae	Larvae	1	120	4	1
Stephen Creek	Riffle	Leuctridae	Larvae	1	4	0.7	1
Hickory Level Creek	Sandy/Silt	Taeniopterygidae	Larvae	1	1	4	1
Shiloh Creek	Riffle	Taeniopterygidae	Larvae	1	1	4	1
Stephen Creek	Riffle	Taeniopterygidae	Larvae	1	1	4	1
Tom's Creek	Woody Debris	Taeniopterygidae	Larvae	1	1	4	1

Stephen Creek	Sandy/Silt	Tipulidae	Larvae	0	1	5.83	1
Stephen Creek	Woody Debris	Tipulidae	Larvae	0	1	5.83	1
Stephen Creek	Riffle	Tipulidae	Larvae	0	1	5.83	1
Stephen Creek	Sandy/Silt	Oligochaeta	NA	0	13	8.27	1
Stephen Creek	Riffle	Oligochaeta	NA	0	4	8.27	1
Stephen Creek	Woody Debris	Gomphidae	Ophiogomphus	0	1	6.2	1
Grove Creek	Woody Debris	Tipulidae	Larvae	0	2	5.83	1
Stephen Creek	Woody Debris	Perlidae	Paragnetia	1	2	1.8	1
Stephen Creek	Sandy/Silt	Gomphidae	Progomphus	0	5	8.7	1
Stephen Creek	Riffle	Chironomidae	Pupae	0	19	NA	0
Sulphur Springs	Riffle	Baetiscidae	Baetisca	1	4	4	1
Sulphur Springs	Woody Debris	Calopterygidae	Calopteryx	0	2	8.3	1
Sulphur Springs	Woody Debris	Cambaridae	Cambarinae	0	1	6	1
Sulphur Springs	Woody Debris	Perlidae	Eccoptura	1	1	4.1	1
Sulphur Springs	Woody Debris	Baetidae	Larvae	1	1	4	1
Sulphur Springs	Sandy/Silt	Capniidae	Larvae	1	1	1	1
Carlan Creek	Sandy/Silt	Lepidostomatidae	Lepidostoma	1	1	1	1
Sulphur Springs	Riffle	Capniidae	Larvae	1	3	1	1
Sulphur Springs	Woody Debris	Capniidae	Larvae	1	135	1	1
Sulphur Springs	Sandy/Silt	Chironomidae	Larvae	0	138	5.79	1

Sulphur Springs	Riffle	Chironomidae	Larvae	0	17	5.79	1
Sulphur Springs	Woody Debris	Chironomidae	Larvae	0	55	5.79	1
Sulphur Springs	Riffle	Gomphidae	Larvae	0	1	5.47	1
Carlan Creek	Woody Debris	Elmidae	Macronychus	0	1	4.7	1
Clouds Creek	Woody Debris	Elmidae	Macronychus	0	2	6	1
Hanna Creek	Sandy/Silt	Elmidae	Macronychus	0	1	4.7	1
Hanna Creek	Woody Debris	Elmidae	Macronychus	0	3	4.7	1
Stephen Creek	Woody Debris	Elmidae	Macronychus	0	1	6	1
Tom's Creek	Sandy/Silt	Elmidae	Macronychus	0	1	4.7	1
Clouds Creek	Riffle	Ancylidae	NA	0	1	7.1	1
Dove Creek	Woody Debris	Ancylidae	NA	0	6	7.1	1
Dove Creek	Sandy/Silt	Ancylidae	NA	0	2	7.1	1
Dove Creek	Riffle	Ancylidae	NA	0	1	7.1	1
Grove Creek	Sandy/Silt	Ancylidae	NA	0	2	7.1	1
Grove Creek	Woody Debris	Ancylidae	NA	0	3	7.1	1
Hickory Level Creek	Sandy/Silt	Ancylidae	NA	0	1	7.1	1
Nails Creek	Woody Debris	Ancylidae	NA	0	1	7.1	1
Sulphur Springs	Riffle	Ancylidae	NA	0	1	7.1	1
Sulphur Springs	Woody Debris	Ancylidae	NA	0	6	7.1	1
Tom's Creek	Woody Debris	Ancylidae	NA	0	2	7.1	1

Hanna Creek	Sandy/Silt	Hydrachnidae	NA	0	1	8	0
Nails Creek	Sandy/Silt	Hydrachnidae	NA	0	3	8	0
Shiloh Creek	Riffle	Hydrachnidae	NA	0	6	8	0
Big Clouds Creek	Woody Debris	NA	NA	0	1	NA	0
Clouds Creek	Riffle	NA	NA	1	5	NA	0
Fork Creek	Woody Debris	NA	NA	0	1	NA	0
Fork Creek	Sandy/Silt	NA	NA	0	1	NA	0
Hickory Level Creek	Woody Debris	NA	NA	0	4	NA	0
Mill Shoals Creek	Sandy/Silt	NA	NA	0	1	NA	0
Stephen Creek	Woody Debris	NA	NA	0	1	6	1
Tom's Creek	Sandy/Silt	NA	NA	0	1	NA	0
Tom's Creek	Woody Debris	NA	NA	0	1	NA	0
Unawatti Creek	Sandy/Silt	NA	NA	0	1	NA	0
Unawatti Creek	Woody Debris	NA	NA	0	3	NA	0
Unawatti Creek	Woody Debris	NA	NA	0	1	NA	0
Big Clouds Creek	Woody Debris	Oligochaeta	NA	0	4	8.27	1
Sulphur Springs	Sandy/Silt	Heptageniidae	Larvae	1	2	2.25	1
Carlan Creek	Woody Debris	Oligochaeta	NA	0	18	8.27	1
Carlan Creek	Sandy/Silt	Oligochaeta	NA	0	3	8.27	1

Sulphur Springs	Riffle	Heptageniidae	Larvae	1	80	2.25	1
Sulphur Springs	Woody Debris	Heptageniidae	Larvae	1	55	2.25	1
Clouds Creek	Woody Debris	Oligochaeta	NA	0	1	8.27	1
Dove Creek	Woody Debris	Oligochaeta	NA	0	4	8.27	1
Dove Creek	Sandy/Silt	Oligochaeta	NA	0	4	8.27	1
Dove Creek	Riffle	Oligochaeta	NA	0	4	8.27	1
Sulphur Springs	Riffle	Hydropsychidae	Larvae	1	56	4	1
Sulphur Springs	Woody Debris	Hydropsychidae	Larvae	1	17	4	1
Sulphur Springs	Woody Debris	Tipulidae	Larvae	0	10	5.83	1
Sulphur Springs	Sandy/Silt	Oligochaeta	NA	0	17	8.27	1
Sulphur Springs	Riffle	Oligochaeta	NA	0	9	8.27	1
Hanna Creek	Sandy/Silt	Oligochaeta	NA	0	1	8.27	1
Sulphur Springs	Woody Debris	Gomphidae	Progomphus	0	1	8.7	1
Sulphur Springs	Sandy/Silt	Chironomidae	Pupae	0	7	NA	0
Mill Shoals Creek	Woody Debris	Oligochaeta	NA	0	1	8.27	1
Sulphur Springs	Riffle	Chironomidae	Pupae	0	4	NA	0
Sulphur Springs	Woody Debris	Chironomidae	Pupae	0	8	NA	0
Tom's Creek	Riffle	Capniidae	Adult	1	1	1	1
Tom's Creek	Woody Debris	Calopterygidae	Calopteryx	0	1	8.3	1
Shiloh Creek	Riffle	Oligochaeta	NA	0	8	8.27	1

Tom's Creek	Riffle	Corbiculidae	Corbicula	0	33	6.3	1
Tom's Creek	Sandy/Silt	Corbiculidae	Corbicula	0	2	6.3	1
Tom's Creek	Riffle	Tipulidae	Hexatoma	0	1	4.7	1
Tom's Creek	Woody Debris	Isonychiidae	Isonychia	1	4	3.8	1
Tom's Creek	Woody Debris	Baetidae	Larvae	1	8	4	1
Tom's Creek	Riffle	Ceratopogonidae	Larvae	0	32	6.65	1
Tom's Creek	Sandy/Silt	Oligochaeta	NA	0	5	8.27	1
Tom's Creek	Woody Debris	Oligochaeta	NA	0	2	8.27	1
Tom's Creek	Sandy/Silt	Ceratopogonidae	Larvae	0	5	6.65	1
Unawatti Creek	Riffle	Oligochaeta	NA	0	4	8.27	1
Tom's Creek	Riffle	Chironomidae	Larvae	0	34	5.79	1
Grove Creek	Sandy/Silt	Planorbidae	NA	0	1	7.45	1
Tom's Creek	Sandy/Silt	Chironomidae	Larvae	0	12	5.79	1
Big Clouds Creek	Sandy/Silt	Sphaeriidae	NA	0	1	7.7	1
Nails Creek	Woody Debris	Sphaeriidae	NA	0	1	7.7	1
Grove Creek	Woody Debris	Veliidae	NA	0	1	6	1
Tom's Creek	Woody Debris	Chironomidae	Larvae	0	16	5.79	1
Tom's Creek	Riffle	Chloroperlidae	Larvae	1	22	0.68	1
Tom's Creek	Woody Debris	Elmidae	Larvae	0	2	3.58	1
Tom's Creek	Woody Debris	Heptageniidae	Larvae	1	16	2.25	1

Tom's Creek	Riffle	Hydropsychidae	Larvae	1	26	4	1
Tom's Creek	Sandy/Silt	Hydropsychidae	Larvae	1	3	4	1
Tom's Creek	Woody Debris	Hydropsychidae	Larvae	1	10	4	1
Tom's Creek	Woody Debris	NA	Larvae	1	2	NA	1
Tom's Creek	Woody Debris	NA	Larvae	1	15	NA	1
Tom's Creek	Woody Debris	Nemouridae	Larvae	1	1	3.27	1
Tom's Creek	Riffle	Oligochaeta	NA	0	12	8.27	1
Tom's Creek	Sandy/Silt	Tricorythidae	Tricorythodes	1	1	5.4	1
Tom's Creek	Woody Debris	Tricorythidae	Tricorythodes	1	1	5.4	1
Unawatti Creek	Woody Debris	Calopterygidae	Calopteryx	0	2	8.3	1
Carlan Creek	Woody Debris	Psocidae	Psocid	0	1	0	0
Carlan Creek	Woody Debris	Chironomidae	Pupae	0	4	NA	0
Unawatti Creek	Sandy/Silt	Corbiculidae	Corbicula	0	13	6.3	1
Unawatti Creek	Woody Debris	Corydalidae	Corydalus	0	1	5.6	1
Clouds Creek	Woody Debris	Chironomidae	Pupae	0	2	NA	0
Dove Creek	Woody Debris	Chironomidae	Pupae	0	2	NA	0
Dove Creek	Riffle	Chironomidae	Pupae	0	1	NA	0
Grove Creek	Sandy/Silt	Chironomidae	Pupae	0	1	NA	0
Grove Creek	Woody Debris	Chironomidae	Pupae	0	8	NA	0
Hanna Creek	Riffle	Chironomidae	Pupae	0	4	NA	0

Hanna Creek	Sandy/Silt	Chironomidae	Pupae	0	2	NA	0
Hanna Creek	Woody Debris	Chironomidae	Pupae	0	8	NA	0
Unawatti Creek	Riffle	Tipulidae	Hexatoma	0	1	5.83	1
Mill Shoals Creek	Woody Debris	Chironomidae	Pupae	0	2	NA	0
Shiloh Creek	Sandy/Silt	Chironomidae	Pupae	0	5	NA	0
Stephen Creek	Sandy/Silt	Chironomidae	Pupae	0	9	NA	0
Stephen Creek	Woody Debris	Chironomidae	Pupae	0	1	NA	0
Unawatti Creek	Sandy/Silt	Baetidae	Larvae	1	2	4	1
Unawatti Creek	Riffle	Baetidae	Larvae	1	7	4	1
Unawatti Creek	Woody Debris	Baetidae	Larvae	1	7	4	1
Unawatti Creek	Sandy/Silt	Chironomidae	Larvae	0	85	5.79	1
Tom's Creek	Riffle	Chironomidae	Pupae	0	8	NA	0
Tom's Creek	Sandy/Silt	Chironomidae	Pupae	0	3	NA	0
Tom's Creek	Woody Debris	Chironomidae	Pupae	0	2	NA	0
Unawatti Creek	Sandy/Silt	Chironomidae	Pupae	0	2	NA	0
Unawatti Creek	Riffle	Chironomidae	Pupae	0	1	NA	0
Fork Creek	Woody Debris	NA	Pupae	0	1	NA	0
Unawatti Creek	Riffle	Chironomidae	Larvae	0	12	5.79	1
Unawatti Creek	Woody Debris	Chironomidae	Larvae	0	4	5.79	1
Unawatti Creek	Woody Debris	Veliidae	Rhagovelia	0	1	6	1

Carlan Creek	Woody Debris	NA	Spider	0	1	0	0
Unawatti Creek	Woody Debris	Elmidae	Larvae	0	3	3.58	1
Unawatti Creek	Riffle	Heptageniidae	Larvae	1	22	2.25	1
Unawatti Creek	Riffle	Hydropsychidae	Larvae	1	59	4	1
Unawatti Creek	Woody Debris	Hydropsychidae	Larvae	1	25	4	1
Unawatti Creek	Woody Debris	Simuliidae	Larvae	0	4	5.07	1
Unawatti Creek	Sandy/Silt	Oligochaeta	NA	0	4	8.27	1
Hanna Creek	Sandy/Silt	Peltoperlidae	Tallaperla	1	1	1.4	1
Unawatti Creek	Woody Debris	Oligochaeta	NA	0	7	8.27	1
Unawatti Creek	Sandy/Silt	Gomphidae	Ophiogomphus	0	1	6.2	1
Clouds Creek	Riffle	Tricorythidae	Tricorythodes	1	1	5.4	1
Hanna Creek	Sandy/Silt	Tricorythidae	Tricorythodes	1	1	5.4	1
Unawatti Creek	Sandy/Silt	Heptageniidae	Stenonema	1	1	7.5	1
Unawatti Creek	Woody Debris	Heptageniidae	Stenonema	1	17	7.5	1
Stephen Creek	Riffle	Vespidae	Wasp	0	1	NA	0

Appendix C. Watershed Social Survey

A. Questions about your property and the Broad River: These 15 questions ask about your land, land management activities, and how you interact with the Broad River and tributaries.

1. Which category below best describes your land ownership? *(Check ONE)*

_____ Individual
_____ Joint, with husband or wife
_____ Corporation or business
_____ Joint with other family member or friends
_____ Family trust or estate
_____ Family partnership or family LLC or LLP

Other (please specify): ________________

2. *If "Individual" was <u>not</u> selected above:* **How many people or business entities are a part of this ownership, including you?** ________________ *people or business entities*

3. Approximately how long have you owned this property or properties adjacent to the Broad River or one of its tributaries? *(Check ONE)*

___ Less than 1 year
___ 11 to 20 years
___ 41 to 50 years
___ 1 to 5 years
___ 21 to 30 years
___ 51 to 60 years
___ 6 to 10 years
___ 31 to 40 years
___ 61+ years

4. Do you currently own more than one property within the Broad River watershed? (i.e., multiple, separate, unconnected parcels of land) *(Check ONE)*

☐ Yes ☐ No

5. Is your home (primary residence) on or within a mile of any of your land within the Broad River watershed? *(Check ONE)*

☐ Yes ☐ No

6. Do you own a secondary home or cabin on or within a mile of any of your land?

☐ Yes ☐ No

7. Approximately how many total acres of land do you currently own within the Broad River watershed? *(Check ONE, consider all parcels if you own more than one)*

___ Less than 100 acres
___ 501 to 750 acres
___ 1501 to 2000 acres
___ 100 to 250 acres
___ 751 to 1000 acres
___ 2001+ acres
___ 251 to 500 acres
___ 1001 to 1500 acres
___ I don't know

8. How important is your <u>land</u> to your annual income? (*Check ONE*)

☐ Not at all important ☐ Somewhat important ☐ Very important ☐ Extremely important

9. On average, approximately what percentage of your household's annual income comes from the <u>land</u> that you own? (*Check ONE*)

☐ 0 to 10% ☐ 11 to 20% ☐ 21 to 30% ☐ 31 to 40% ☐ 41 to 50% ☐ 51 to 60%
☐ 61 to 70% ☐ 71 to 80% ☐ 81 to 90% ☐ 91 to 100% ☐ I don't know

10. Have development rights been sold or voluntarily donated on any of your land in the form of a <u>conservation easement</u> by either you or a previous owner? *(Check ONE)*

☐ Yes ☐ No ☐ I don't know

11. Which branch of the Broad River are you closest to? *For reference, consult the attached information sheet for a map of the branches of the Broad River. (Check ALL below that apply if you own more than one property, or are adjacent to more than one branch)*

Banks County:

_____ Middle Fork	_____ Nancy Town Creek	_____ Hudson River
_____ Little Nails Creek	_____ Mountain Creek	_____ Grove Creek
_____ Black Creek	_____ Nails Creek	

Elbert County:

_____ Broad River	_____ Millstone Creek	_____ Deep Creek
_____ Dove Creek	_____ Falling Creek	_____ Dry Fork
_____ Wahachee Creek	_____ Bertrams Creek	_____ Cooter Creek

Franklin County:

_____ North Fork	_____ Toms Creek	_____ Clark Creek
_____ Double Branch	_____ Unawaie Creek	_____ Rice Creek
_____ Hannah Creek	_____ Middle Fork	_____ Hudson River
_____ Black Creek	_____ Nails Creek	

Habersham County:

_____ North Fork	_____ Middle Fork	_____ Nancy Town Creek

Hart County:

_____ Double Branch	_____ Millstone Creek	

Madison County:

_____ Broad River	_____ Hannah Creek	_____ Millstone Creek
_____ Hudson River	_____ Black Creek	_____ Shiloh Creek
_____ Bluestone Creek	_____ Skull Shoals Creek	_____ Holly Creek
_____ South Fork	_____ Fork Creek	_____ Rocky Shoals Creek
_____ Beaverdam Creek	_____ Brush Creek	_____ Biger Creek

Oglethorpe County:

_____ South Fork	_____ Beaverdam Creek	_____ Big Clouds Creek
_____ Grove Creek	_____ Broad River	_____ Millstone Creek
_____ Long Creek	_____ Macks Creek	_____ Indian Creek
_____ Buffalo Creek	_____ Dry Fork Creek	

Stephens County:

_____ North Fork	_____ Toms Creek	_____ Clark Creek
_____ Middle Fork		

Wilkes County:

_____ Broad River	_____ Long Creek	_____ Dry Fork Creek
_____ Clarks Creek	_____ Chickassaw Creek	

Other:

I don't know / I'm not sure: _____
Not listed (please specify): ____

12. Please indicate both: *(Circle ONE for each question on each row)*

A) Which of the following have occurred on your land in the past 5 years, and

B) How likely are the following activities to occur on your land in the next 5 years?

Land management activities	**Has occurred in the last 5 years?**		**How likely to occur in next five years?**				
			Not Likely	Somewhat Likely	Likely	Very Likely	Extremely Likely
Cut and/or removed trees for sale	Yes	No	1	2	3	4	5
Cut and/or removed trees for own use	Yes	No	1	2	3	4	5
Collected non-timber forest products, such as berries or mushrooms	Yes	No	1	2	3	4	5
Reduced fire hazard (such as firebreak installation)	Yes	No	1	2	3	4	5
Controlled burn/prescribed fire	Yes	No	1	2	3	4	5
Tree planting/reforestation	Yes	No	1	2	3	4	5
Planned natural regeneration of trees	Yes	No	1	2	3	4	5
Eliminated or reduced invasive plants	Yes	No	1	2	3	4	5
Eliminated or reduced unwanted insects or diseases	Yes	No	1	2	3	4	5
Herbicide/pesticide application for removing plants/pests	Yes	No	1	2	3	4	5
Improved wildlife habitat (other than through invasive plant/pest removal)	Yes	No	1	2	3	4	5
Water quality practices (such as repaired/installed culverts or water bars, fixed stream crossings)	Yes	No	1	2	3	4	5
Road construction or maintenance	Yes	No	1	2	3	4	5
Trail construction or maintenance (for hiking or off-road vehicles)	Yes	No	1	2	3	4	5
Livestock grazing	Yes	No	1	2	3	4	5
Installed/added food plots or new fields	Yes	No	1	2	3	4	5
Other (please specify):							

13. Which of the following activities related to the Broad River and surrounding land:

A) Have you participated in within the past 5 years, and

B) How likely are you to participate in these activities in the next 5 years?

(Circle ONE for each question on each row)

Broad River-related activities	**Have participated in within the last 5 years?**		**How likely to participate in within next five years?**				
			Not Likely	Somewhat Likely	Likely	Very Likely	Extremely Likely
Walking or hiking near the River	Yes	No	1	2	3	4	5
Nature walk (such as bird watching)	Yes	No	1	2	3	4	5
Picnic or social gathering near the River	Yes	No	1	2	3	4	5
Swimming in the Broad River	Yes	No	1	2	3	4	5
Paddling in the Broad River	Yes	No	1	2	3	4	5
Fishing in the Broad River	Yes	No	1	2	3	4	5
Hunting near the Broad River	Yes	No	1	2	3	4	5
Cleaned up trash or pollution in/near the River	Yes	No	1	2	3	4	5
Participated in a community conservation event	Yes	No	1	2	3	4	5
Camping near the Broad River	Yes	No	1	2	3	4	5
Other (please specify):							

14. Approximately how frequently do you interact with the Broad River in a way that is meaningful to you? *(Check ONE)*

_____ At least once per week
_____ Approximately once per month
_____ Once every few months
_____ Approximately once per year
_____ Once every few years
_____ Almost never
_____ Never
Other (please specify): ___________________

15. Please list any notable interaction(s) you have with the Broad River not listed above:

____

____

____

B. Questions about your sources of information and engagement: These 7 questions ask about how you get information on the Broad River.

16. Please rank your top THREE ranked preferred <u>sources of information related to the Broad River</u>? *(Please write 1, 2, and 3 for top three options in a ranked order, with 1 as your top choice and 3 as third choice)*

____ Cable television	____ Network television
____ Public television	____ Local newspapers
____ Major newspapers	____ Extension
____ Universities	____ Schools
____ Environmental agencies	____ Environmental groups
____ Magazines	____ Radio
____ Friends and family	Other (please specify):______________________

17. Which of the following <u>land management and conservation organizations</u> do you recall:
A) <u>receiving information from</u> (e.g., mailing, workshop, personal interaction) OR
B) <u>actively interacting with</u> (e.g., membership, consultation, program involvement)
in the past 5 years? *(Circle ONE for each section for each row)*

Land management and conservation organization	Received information from	Actively interacted with
University Extension Service (such as University of Georgia)	Yes No	Yes No
State Wildlife Agency (Department of Natural Resources (DNR))	Yes No	Yes No
State Natural Resources Agency (Georgia EPD)	Yes No	Yes No
Local or Regional Non-Governmental Organization (NGOs) (such as the Broad River Watershed Association)	Yes No	Yes No
State or National Conservation Organization (such as The Nature Conservancy)	Yes No	Yes No
Natural Resource Conservation Service (NRCS)	Yes No	Yes No
Farm Service Agency (FSA)	Yes No	Yes No
U.S. Fish and Wildlife Service (USFWS)	Yes No	Yes No

18. Please list any other <u>community-based groups / organizations</u> related to the recreational use or stewardship of the Broad that you have either a <u>membership or affiliation with</u>:

____

____

____

19. Please indicate which of the following specific <u>organizations you've heard of</u> before this survey:
(*Circle ONE for each row)*

USDA Natural Resources Conservation Service (NRCS)	Yes	No	I don't know
GA Environmental Protection Division (EPD)	Yes	No	I don't know
GA Soil and Water Conservation Commission (GSWCC)	Yes	No	I don't know
Broad River Watershed Association (BRWA)	Yes	No	I don't know
Savannah Riverkeeper	Yes	No	I don't know

<u>For the next few questions, use the following information:</u>

The Broad River Watershed Association (BRWA) is a non-profit regional land trust dedicated to preserving Georgia's river corridors, undeveloped open space, wetlands, wildlife habitat, forestland, farm land, and unique natural ecosystems within the Broad River basin. BRWA's goal is to ensure, through work with local landowners, local governments, and state agencies, that these natural resources will enhance the quality of life in our region for present and future generations to come.

20. To what extent <u>did you know BRWA before this survey</u>? (*Check ONE)*

__ Never heard of it __ Heard the name __ Knew it somewhat __ Knew it well __ Member

21. To what extent do you agree or disagree with the following statements: *(Circle ONE for each)*

Indicate how much you agree or disagree with the following:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Organizations like BRWA are a part of the local community	1	2	3	4	5
The work of local organizations benefits the valuable natural resources	1	2	3	4	5
The work organizations like BRWA does is communicated clearly	1	2	3	4	5
I trust that organizations like BRWA will work with me to improve my quality of life	1	2	3	4	5

22. How much are the following <u>potential barriers to engaging with organizations like BRWA?</u>

How much are the following potential barriers to engaging with conservation organizations like BRWA?	Not a barrier	Minor barrier	Moderate barrier	Major barrier
Unsure about the work of conservation organizations	1	2	3	4
Limited or unclear information about available programs	1	2	3	4
Takes too much time to participate	1	2	3	4
Too much travel to other areas to participate	1	2	3	4
Other (please specify):				

C. Questions about You and Your Opinions: The following information provides us with a foundation for understanding the information you provided in the earlier questions and helps find similarities and differences among landowners in the Broad River watershed. This information is being collected solely for research purposes and will not be shared, sold, used for solicitation, or made public.

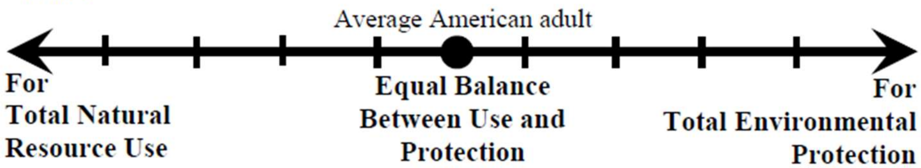
23. How important are each of the following water issues to you? *(Circle ONE for each row)*

Issue:	Not important	Somewhat important	Important	Very important	Extremely important
Clean rivers and lakes	1	2	3	4	5
Clean marine water	1	2	3	4	5
Clean drinking water	1	2	3	4	5
Clean groundwater	1	2	3	4	5
Water for commerce/industry/ power generation	1	2	3	4	5
Water for household landscapes	1	2	3	4	5
Water for agriculture	1	2	3	4	5
Water for recreation	1	2	3	4	5
Water for municipal use	1	2	3	4	5
Interstate transfer/sale of water rights	1	2	3	4	5
Within state transfer/sale of water rights	1	2	3	4	5

24. In your opinion, which of the following are most responsible for the existing pollution problems in rivers and lakes in your state? *(Check up to 3 answers)*

___ Forestry (wood harvesting)
___ Agriculture – animals
___ Industry
___ Septic systems
___ Stormwater runoff
___ Wastewater treatment plants
___ Oil wells and mining
___ Agriculture – crops
___ Erosion from roads and/or construction, repair
___ Military bases
___ Runoff from home landscapes
___ Landfills
___ New suburban development
Other (please specify):______________________

25. Please place an X on the line below to indicate how you see yourself on environmental issues:



26. How <u>important</u> are the following as <u>reasons for why you currently own your land</u>? *If you own more than one property, consider them all and select one response for all your land. (Circle ONE for each row)*

Reasons for owning land:	**Not important**	**Somewhat important**	**Important**	**Very important**	**Extremely important**
To enjoy beauty or scenery	1	2	3	4	5
To protect nature (plant and wildlife communities)	1	2	3	4	5
To protect water resources	1	2	3	4	5
For land investment	1	2	3	4	5
For privacy	1	2	3	4	5
To raise my family	1	2	3	4	5
To pass land on to my children or other heirs	1	2	3	4	5
For firewood	1	2	3	4	5
For frequent harvest of forest products	1	2	3	4	5
For timber products, such as logs or pulpwood	1	2	3	4	5
For nontimber forest products, such as berries or mushrooms	1	2	3	4	5
For hunting	1	2	3	4	5
For fishing	1	2	3	4	5
For recreation, other than hunting	1	2	3	4	5
For my community	1	2	3	4	5
Other (please specify):					

27. Please indicate <u>how concerned you are</u> about each of the following topics. *(Circle ONE for each row)*

Indicate how concerned you are about the following:	No concerned	Mildly concerned	Somewhat concerned	Moderately concerned	Very concerned
Keeping land intact for future generations	1	2	3	4	5
Development of nearby lands	1	2	3	4	5
Invasive plants	1	2	3	4	5
Unwanted insects or diseases	1	2	3	4	5
Wildfire	1	2	3	4	5
Protecting drinking water	1	2	3	4	5
Drought or lack of water	1	2	3	4	5
Air pollution	1	2	3	4	5
Climate change	1	2	3	4	5
Agricultural waste or contamination	1	2	3	4	5
Misuse of wooded land, such as vandalism or dumping	1	2	3	4	5
Damage or noise from off-road vehicles or public road traffic	1	2	3	4	5
Trespassing or poaching	1	2	3	4	5
Recreation in the area by non-residents	1	2	3	4	5
Government regulation	1	2	3	4	5
High property taxes	1	2	3	4	5
Other (please specify):					

D. Now, we'd like to find out a little bit about you: Once again, this information is being collected solely for research purposes and will never be shared, sold, used for solicitation, or made public.

28. What is your age? ____ *in years*

29. What is your gender? (*Check ONE*)

☐ Male ☐ Female ☐ Prefer not to answer

30. What is the highest degree or level of school you have completed? (*Check ONE*)

___ Less than 12th grade ___ High school/GED ___ Some college
___ Associate degree ___ Bachelor's degree ___ Advanced degree
___ Prefer not to answer

31. Would you like to learn more about any of the following water quality issue areas? *(Check all that interest you)*

___ Watershed management ___ Watershed restoration
___ Irrigation management ___ Shoreline clean-up
___ Animal waste management ___ Nutrient and pesticide management
___ Private well protection ___ Septic system management
___ Protecting public drinking water supplies ___ Water policy and economics
___ Community actions concerning water issues ___ Fish and wildlife water needs
___ Restoring fish and aquatic habitat ___ Landscape buffers
___ Home and garden landscaping Other (please specify):____________

32. If you had the following kinds of learning opportunities to learn more about water issues, which would you be most likely to take advantage of? *(Check up to 3 items)*

___ Visit a web site ___ Take a course for certification or credit
___ Attend a short course or workshop ___ Look at a demonstration or display
___ Read a newspaper article or series ___ Watch TV coverage
___ Watch a video of information ___ Attend a fair or festival
___ Read printed fact sheets, bulletins, or brochures
___ Take part in a onetime volunteer activity (for example, water monitoring, streamside restoration, or education)
___ Get trained for a regular volunteer position (for example, as a watershed steward or a water quality monitor)

Any additional comments, questions, or concerns: ________________________

____

____

____

Appendix D

R programming code for Macroinvertebrate Analysis

```
library(dplyr)
library(ggplot2)
library(lme4)
library(tidyr)

# import data from appendix B.1 & B.2
# totals for 'aquatic insects included'  by stream and habitat
stream.macros<-Invert_data_Broad_15march.Table.1%>%filter(Include==1)%>%group_by(Stream, Habitat)%>%summarize(total=sum(Number)) #appendix b.2

#  total EPT by stream and habitat
stream.ept<-Invert_data_Broad_15march.Table.1%>%filter(EPT==1)%>%group_by(Stream, Habitat)%>%summarize(total.ept=sum(Number))
# put them together
stream.macros.ept<-merge(stream.macros, stream.ept)

## file with land cover data
Land.Coverage.Datasheet <- read.csv("~/Library/Mobile Documents/com~apple~CloudDocs/current files/grads_2023/jasmine/data_code_7_Oct/Land Coverage Datasheet.csv") #appendix b.1
View(Land.Coverage.Datasheet)
stream.data<-Land.Coverage.Datasheet[ ,c(1,4,8:11)]
stream.data$order<-c(11, 3,13,15,14,12,7,1,10,2,8,6,9,4,5). # so we can plot from upstream to downstream in watershed
stream.data$position<-ifelse(stream.data$order<9, 'upper', 'lower') # so we can plot upper vs lower
stream.data$num.habitats<-c(2,2,3,3,2,2,3,2,3,2,2,3,3,3,3) # so we can plot mean tolerance or percent EPT in relation to number of habitats

## harmonize stream names
stream.macros.ept$Stream<-ifelse(stream.macros.ept$Stream=="Mill Shoals Creek", "Mill Shoal Creek", stream.macros.ept$Stream)
stream.macros.ept$Stream<-ifelse(stream.macros.ept$Stream=="Sulphur Springs", "Sulphur Springs Creek", stream.macros.ept$Stream)
stream.macros.ept$Stream<-ifelse(stream.macros.ept$Stream=="Dove Creek ", "Dove Creek", stream.macros.ept$Stream)
stream.data$Stream<-ifelse(stream.data$Stream=="Sulpur Springs Creek", "Sulphur Springs Creek",stream.data$Stream)
stream.all<-merge(stream.macros.ept, stream.data)


### totals and ept.totals by stream
totals.by.stream<-stream.macros.ept%>%group_by(Stream)%>%summarise(all.ind=sum(total), all.ept=sum(total.ept))

## proportion of all individuals that are in the EPT orders
totals.by.stream$proportion.ept<-totals.by.stream$all.ept/totals.by.stream$all.ind
## add this to the stream.data
stream.data.everything<-merge(stream.data, totals.by.stream)
```

```
## linear regressions
summary(ept.prop<-lm(proportion.ept~Urban.per, data=stream.data.everything))

## logit regression, proportion EPT
stream.data.everything$not.ept<-stream.data.everything$all.ind-stream.data.everything$all.ept
summary(ept.prop<-glm(cbind(all.ept, not.ept)~Urban.per, data=stream.data.everything,
family=binomial(link=logit)))
summary(ept.prop<-glm(cbind(all.ept, not.ept)~Ag.per, data=stream.data.everything,
family=binomial(link=logit)))
summary(ept.prop<-glm(cbind(all.ept, not.ept)~Forest.per, data=stream.data.everything,
family=binomial(link=logit)))

summary(ept.prop<-glm(cbind(all.ept, not.ept)~Basin.Size.sq.miles., data=stream.data.everything,
family=binomial(link=logit)))

### differences among habitats
total.model<-lmer(total~Habitat + (1|Stream), data=stream.all)
summary(total.model)

total.means<-stream.all%>%group_by(Habitat)%>%summarise(mean_ind=mean(total))

ept.model<-lmer(total.ept~Habitat + (1|Stream), data=stream.all)
summary(ept.model)

ept.means<-stream.all%>%group_by(Habitat)%>%summarise(mean_ind=mean(total.ept))

### land cover models all followed this format

Sand.Agr.Analysis<-lm(Sand.ind ~Ag.per , data = land.hab)
summary(Sand.Agr.Analysis)
```