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Fish Community Structure in Relation to Habitat and Disturbance in the Lake James Watershed

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Abstract

Fish assemblages' interrelation to habitat complexity, structure, and disturbance was studied within the Lake James Watershed. Under stable conditions, increased habitat variability typically promotes fish species diversity. However, disturbance can also play a role in both promoting and limiting fish diversity. Nineteen sites were sampled within small to mid-sized streams to test these hypotheses. Results indicated that habitat variability and disturbance played no role in species diversity. However, certain environmental variables, especially temperature, proved to play important roles in determining presence and absence of certain species like the Salmonids. These trends appeared to show environmental gradients across sites, representing habitat variables and fish species of headwater and downstream portions of streams.

1. Introduction

Analyzing species composition in relation to habitats among watersheds can reveal a variety of patterns within fish assemblages. Habitat structure regulates fish species diversity through substrate size, stream width, depth, and flow[1,2]. Depending on size, fish species utilize these instream factors differently as larger species utilize deeper water to avoid predation from terrestrial animals[3]. Water temperature, dissolved oxygen content, conductivity, pH, and turbidity can all play a role in driving less tolerant species away from a section of a stream[4,5]. In combination with these physical features, wider, downstream regions of rivers and streams have been found to support a higher abundance of fish species, while headwaters contain colder, faster moving sections with less species diversity[6.7]. Different species also tend to be less selective when considering habitat; Percids, Catostomids, and Cyprinids have all been noted to occupy several habitat types among streams[8]. Fish assemblages also relate to different microhabitats based on life stage, for example, juveniles of species typically found in pools use riffles as a refuge to avoid predation[9].

Habitat structure is strongly influenced by the land use surrounding the stream. Nutrients, sediment load, and hydrologic characteristics all depend directly on the land use[10]. Agricultural and urban land surrounding instream habitat show negative trends when considering fish species diversity due to the lack of vegetative buffer and an increase in the amount of impervious surfaces[11,10]. In Western North Carolina, agricultural and urban land use influence most of the shifts in trophic roles as a result of increased concentrations of metals and soil erodibility[12]. All these variables can cause frequent disturbance events within streams, which can eliminate sensitive fish species[13]. Streams with intermediate levels of disturbance are expected to have the highest species diversity[2].

It is also important to consider riffle-pool relationships when examining fish assemblages. Species specialize within pools and riffles, so when comparing assemblages among sites it is important to not group riffle and pool data since patterns and processes are drastically different between microhabitats[9]. These aspects of instream habitat play a primary role in directing fish assemblages to certain locations within a watershed.

The goal of this study was to find patterns of fish assemblages dependent on habitat and disturbance within the Lake James watershed. The following question was addressed: how does habitat variation, disturbance, and instream environmental gradients determine differences in fish communities?

2. Methods

The Lake James watershed spans 247,475 acres located at the headwaters of the Catawba and Linville rivers. The sites we surveyed include 19 mid-sized to small streams within McDowell and Burke counties that were previously sampled by the Lake James Environmental Association. Research was performed throughout the months of June and July 2019.

Each site spanned 50 m of stream marked by flags. We divided these 50 m sections into five transects. We then divided these transects into points where we captured fishes using a kick seine net, and measured habitat from downstream to upstream. The number of points within transects was dependent on the width of the stream, varying from 2-5 points. We sampled each point with the seine net, approximately 1 m^2 every kick, while marking them immediately after with bobbers connected to weights to ensure that habitat variables were then measured accurately. If any fish were captured, they were recorded and placed in buckets to ensure that there was no recapture. After netting we measured the substrate size, depth, and flow velocity at each of the marked points within the transects. At each point we measured water depth and flow velocity with a water flow probe (Global Water Instrumentation Inc.), and classified substrate into seven different sizes: silt, sand, gravel, pebble, cobble, boulder, and bedrock[14]. Once all instream habitat variables were measured, we then electro-fished the entire site, storing fish once captured, and identified then recorded species. Some species were preserved to later be identified in the lab. At the upstream end of each site we measured dissolved oxygen and conductivity, a measure of dissolved ions that limit fish distributions. Temperature values were obtained by data loggers that we placed in streams throughout the month of July. We ensured that two pools and two riffle habitats were accounted for when taking all measurements[15].

To analyze data, we utilized multiple techniques. To determine habitat requirements, we plotted average depth and flow of each species captured via netting. Secondly, to determine the effects of habitat diversity on species diversity, we used the Shannon-Weiner diversity index in order to examine the relationship between four types of categorical variables within sites: substrate, depth, flow, and a combination of depth and flow[2]. We organized flow and depth into 4 categories, while 7 for substrate were recognized in order perform diversity index calculations (Table 1). To assess potential niche overlap among species we plotted the range and average depth at which every species occurred. To assess potential disturbance impacts on fish species, we plotted the relationship between the number of fish species per site with stream conductivity and land use percentages obtained from ArcMap (agricultural and urban), both being used as the measurement of disturbance from pollution[16]. To identify differences in fish assemblages across sites and to identify important environmental variables, we used a correspondence analysis between all species and sites using PCORD 5 and Microsoft Excel[17]. We then correlated the mean of flow and depth, along with dissolved oxygen, conductivity, average July temperature and substrate percentage from each site with corresponding Axis scores for the entirety of the dataset, along with a reduced version excluding outliers.[15]

Table 1. Descriptions of instream habitat variable categories used in Shannon-Weiner index calculations

	Habitat Category Number						
	1	2	3	4	5	6	7
Substrate	Clay/Silt	Sand	Gravel	Pebble	Cobble	Boulder	Bedrock
Depth (cm)	0-25	25-35	35-45	>45			
	Very Shallow	Shallow	Moderate	Deep			
Flow (m/s)	.0-0.25	0.25-0.35	0.35- 0.5	>0.5			
	Very Slow	Slow	Moderate	Fast			

3. Results

We collected a total of 485 fish totaling 28 species. Seven families within four different orders were represented including Cypriniformes, Perciformes, Salmoniformes, and Siluriformes. Thirteen different Cypriniform species were collected along with nine different Perciformes, three Salmoniformes, and two Siluriformes. *Nocomis leptocephalus* was the most common species occurring at every site excluding two. Seven species only occurred at one site each.

Sites within the North Fork of the Catawba River and the Linville River represented the highest conductivity values (Table 2). Paddy's and Curtis Creek, two heavily forested tributaries, showed the lowest conductivity values. Most sites on the Linville and Mills River, both reside at higher altitudes, showed the lowest values for temperature. Streams within close proximity to the lake or at lower altitudes tended to show higher temperatures. Dissolved oxygen remained fairly consistent with no notable outliers. Substrate types and flow values varied greatly across all sites. Some data points are missing under temperature as a result of lost temperature data loggers in the field.

Habitat use of fish species across all sites varied, but a clear grouping of pool and riffle species is shown (Figure 1). Salmoniformes and *Etheostoma brevispinum* were present in the highest flows while Centrarchids like *Lepomis auratus* and some Cypriniforms like *Hypentelium nigricans* were found in deeper, slower flowing water. Most other species were grouped between 0.14-0.38 m/s when considering flow and 13-45 cm when considering depth.

After fish species diversity was regressed with habitat diversity no significant values were found for flow, depth or substrate ($p > 0.05$; Figure 2 A.-D.). When flow and depth were combined the results yielded no significance ($p > 0.05$).

When ranges were plotted, a high amount of overlap was shown (Figure 3). *Lepomis auritus* was the only species found at the same depth twice. Generally, where one species occurred, three or more others existed within the same range. Species that exhibited no range either were only found once or multiple times at the same depth or flow.

When conductivity was plotted in relation to total number of fish species per site no significant correlation was found ($p > 0.05$; Figure 4)). Site four (North Fork Catawba at American Thread Road) was an outlier as it had high values of both conductivity and species count (86.3 µS/cm and 13 fish species).

In the correspondence analysis, grouping of cold-water Salmonids is shown with sites seven, six and 13 (Figure 5). Site 18 was grouped with Perciformes *Micropterus salmoides* and *Etheostoma olmstedi*. Axis 1 showed a significant negative relationship with water temperature ($r < -.44$), but Axis 2 had no significant correlations with any environmental variable.

Once outliers were eliminated, secondary trends in the correspondence analysis were evident (Figure 6). Axis 1 had a significant negative correlation with conductivity ($r < -.44$), temperature ($r < -.44$), flow ($r < -.44$) and depth ($r < -.44$), while also showing a significant positive correlation with percent gravel/pebble substrate ($r > .44$). Axis 2 showed a significant negative correlation in depth ($r < -.44$).

Table 2. Site number and corresponding mean values for environmental variables

Site	*Conductivity (µS/cm)*	*Jul. Mean Temp. (℃)*	*D.O. (mg/L)*	*Mean Flow (m/s)*	*Mean Depth (cm)*	*% Silt/Sand*	*% Grav/Peb*	*% Cobble +*
1. Catawba River at Old Fort Park	47.3	20.3	8.41	0.36	32.3	0	16	84
2. Mill Creek at Old Fort	37.4	21.5	8.51	0.26	55	19.8	14.5	65.7
3. Upper Toms	22	19.9	8.3	0.39	22.3	23	24	53
4. North Fork Catawba at American Thread Road	86.3	-	8.43	0.25	50.7	38.2	40.2	21.6
5. North Fork Catawba at School Road	65.7	22.4	8.18	0.38	34.8	3	5.5	91.5
6. Linville at Mill Timber Creek	67.9	18.2	8.09	0.39	28.6	27.3	16.6	56.1
7. Upper Mills River at Andrews Geyser	22.7	19.2	8.69	0.42	49	0	10.5	89.5
8. Curtis Creek	19.41	-	8.47	0.29	29.9	4.5	46.4	49.1

9. Crooked Creek Upstream	43.4	20.41	8.69	0.42	32.8	32.5	48.5	19
10. Catawba River at Parker Padgett Rd	45.9	-	8.37	0.37	50	29.5	14.4	56.1
11. Crooked Creek Downstream	41.2	21.6	8.75	0.45	32.3	0.5	68.9	30.6
12. Buck Creek	28.2	-	8.12	0.45	47.3	1	39.3	59.7
13. Linville River at 221	60.7	19.2	8.36	0.4	29.8	6.3	13.1	80.6
14. Linville at Pineola	55.7	-	8.3	0.51	38.4	2.5	21.7	75.8
15. Linville at Griffin Cottage	51.4	23.9	8.42	0.48	32.72	8.8	1.3	89.9
16. White Creek	24.4	-	8.16	0.21	22.7	21.4	50	28.6
17. Mackey Creek	25.3	2-4.9	8.26	0.34	38.8	15.4	19.2	65.4
18. Paddy's Creek	19.2	22.1	8.09	0.19	32.6	0	45	55
Mean	42.45	21.13	8.36	0.36	36.66	12.98	27.5	59.51

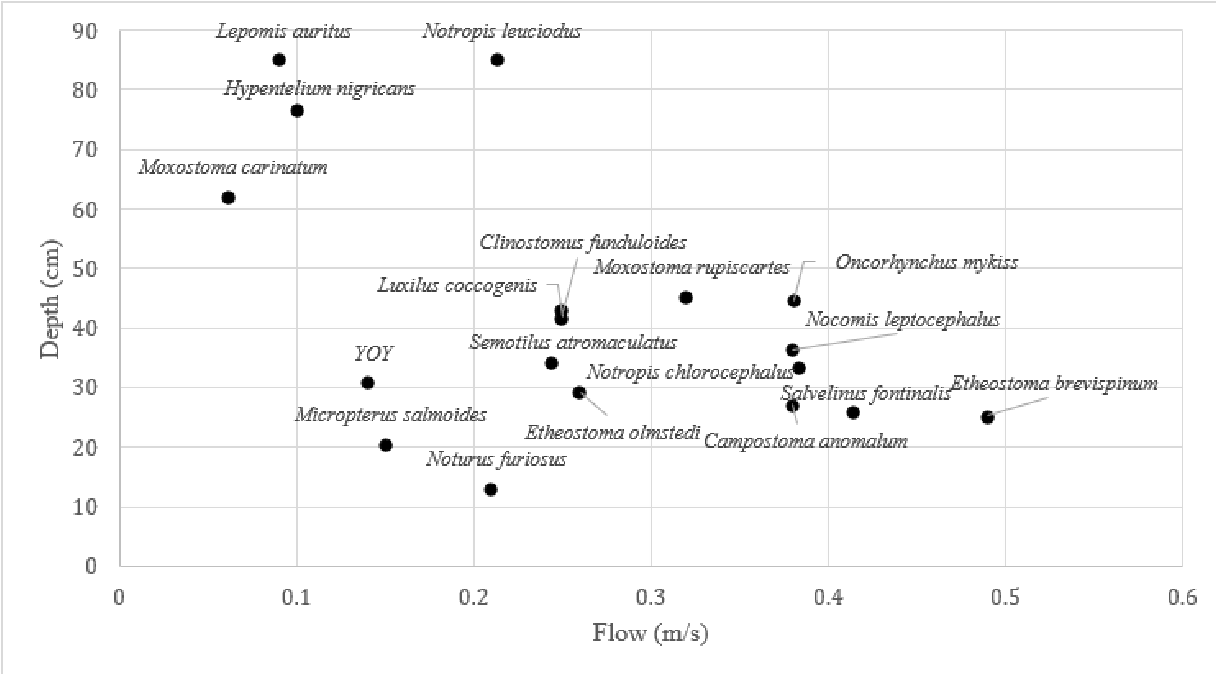

Figure 1. Mean depth and flow velocity of all kick seine collected species across all sites

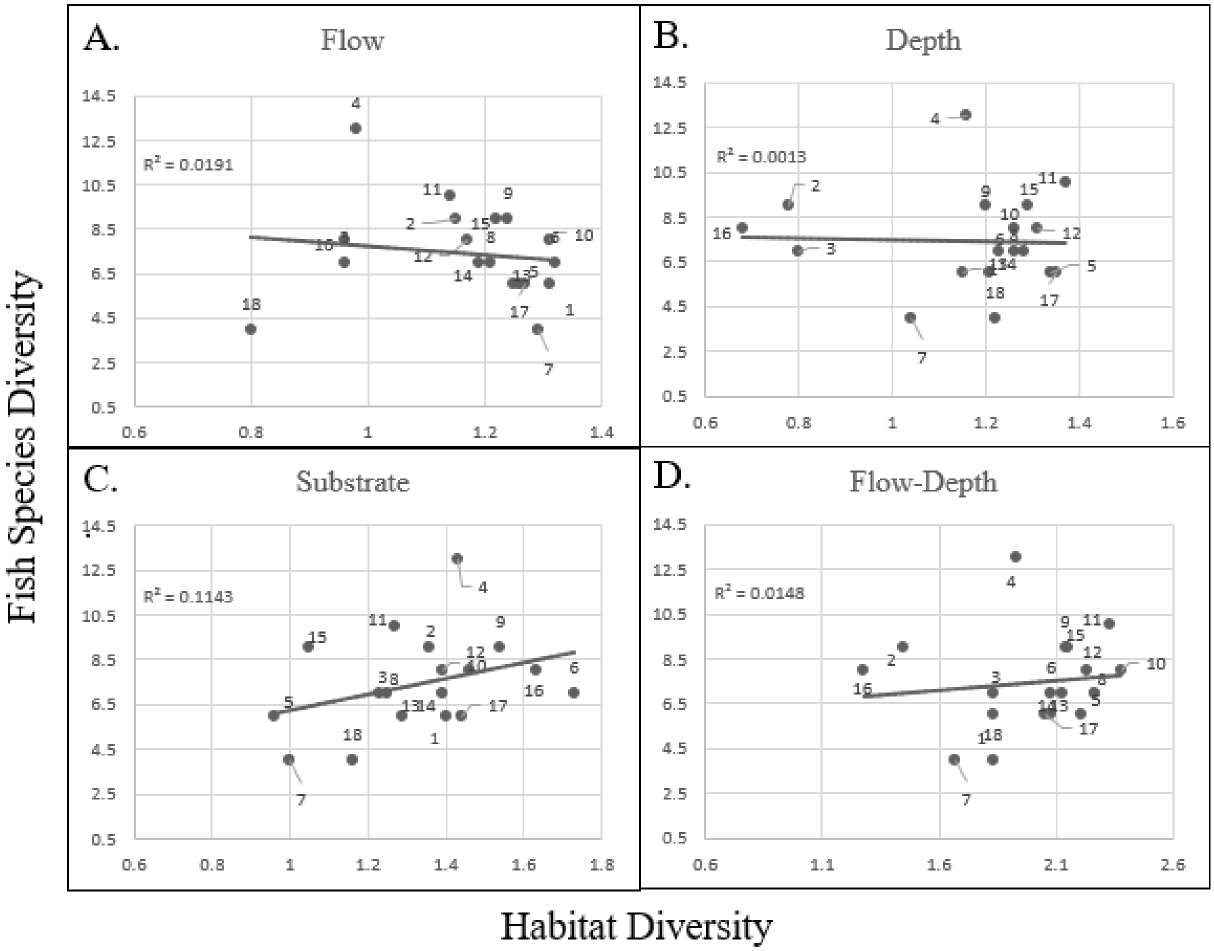

Figure 2 A.-D. Shannon-Weiner diversity indices for all sites based on flow, depth, substrate, and flow-depth diversity in relation to fish species diversity, data labels represent sites

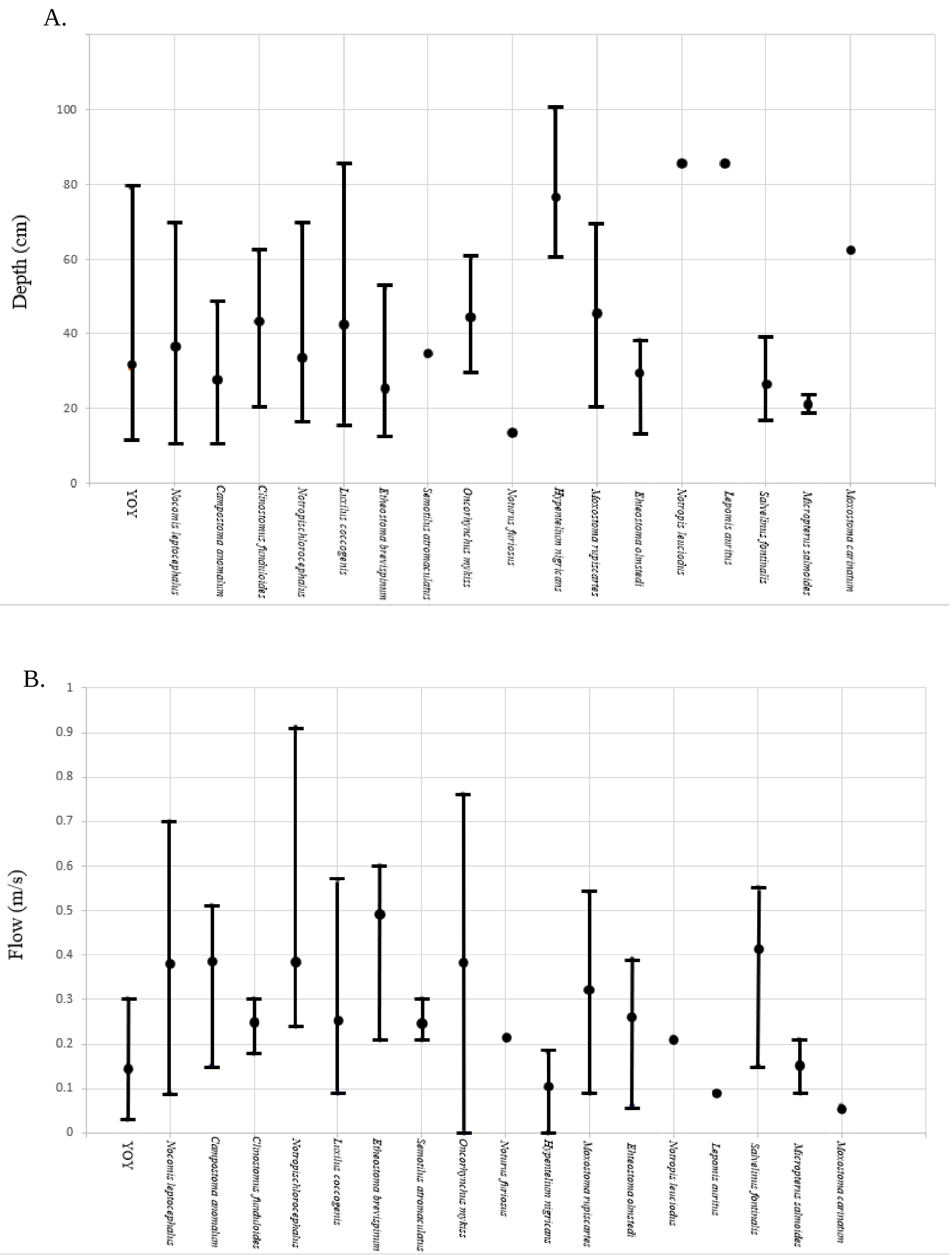

Figure 3 A.-B. Mean and range of water depths and flow velocities occupied by fish species across all sites

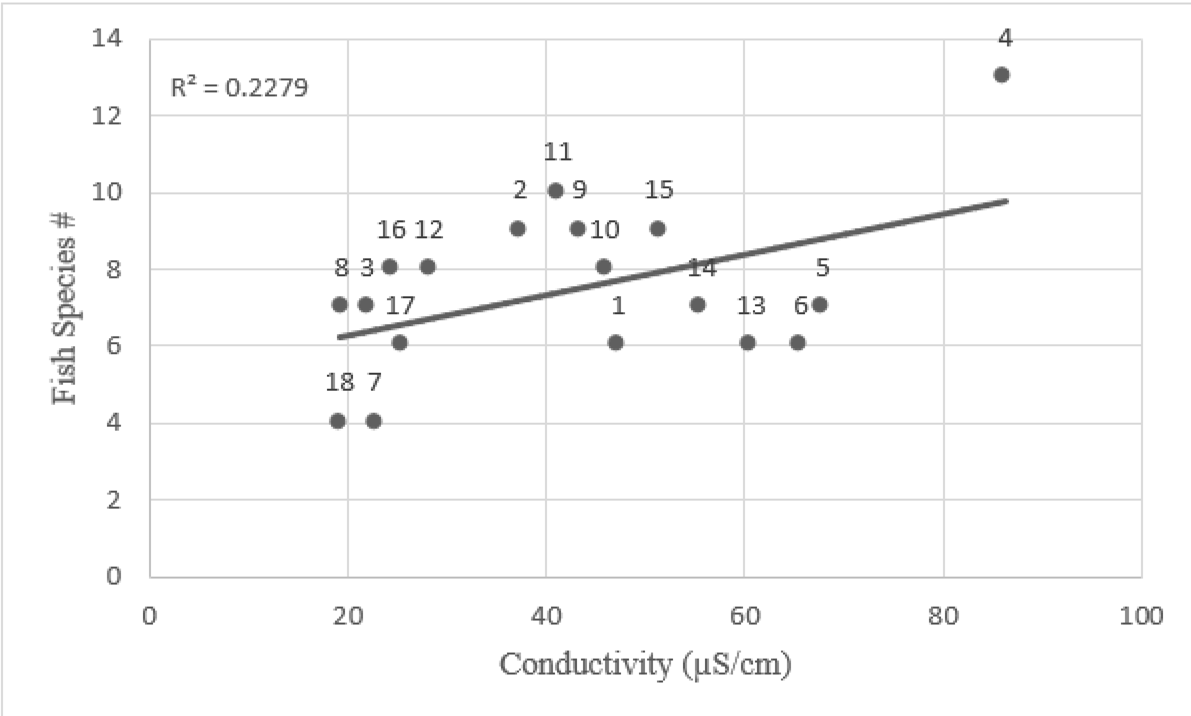

Figure 4. Relationship between conductivity and number of fish species. Data labels represent sites

Table 3. Abbreviations of 26 fish species for correspondence analysis graphs

Species	Abbreviation
Nocomis leptocephalus	BHC
Campostoma anomalum	CS
Clinostomus funduloides	RSD
Notropis chlorocephalus	GHS
Luxilus coccogenis	WPS
Etheostoma brevispinum	CFD
Semotilus atromaculatus	CC
Oncorhynchus mykiss	RTrt
Noturus furiosus	MTm
Hypentelium nigricans	NHS
Moxostoma rupiscartes	JR
Etheostoma olmstedi	TD
Notropis leuciodus	TnS
Lepomis auritus	RB
Salvelinus fontinalis	BkTrt
Micropterus salmoides	LMB
Moxostoma carinatum	RH
Percina crassa	PrD

Notropis hudsonius	STS
Cyprinella galactura	WTS
Lepomis cyanellus	GrnS
Notropis rubricroceus	SS
Salmo trutta	BrTrt
Ambloplites rupestris	RB
Lepomis macrochirus	BG
Ameiurus melas	BCat

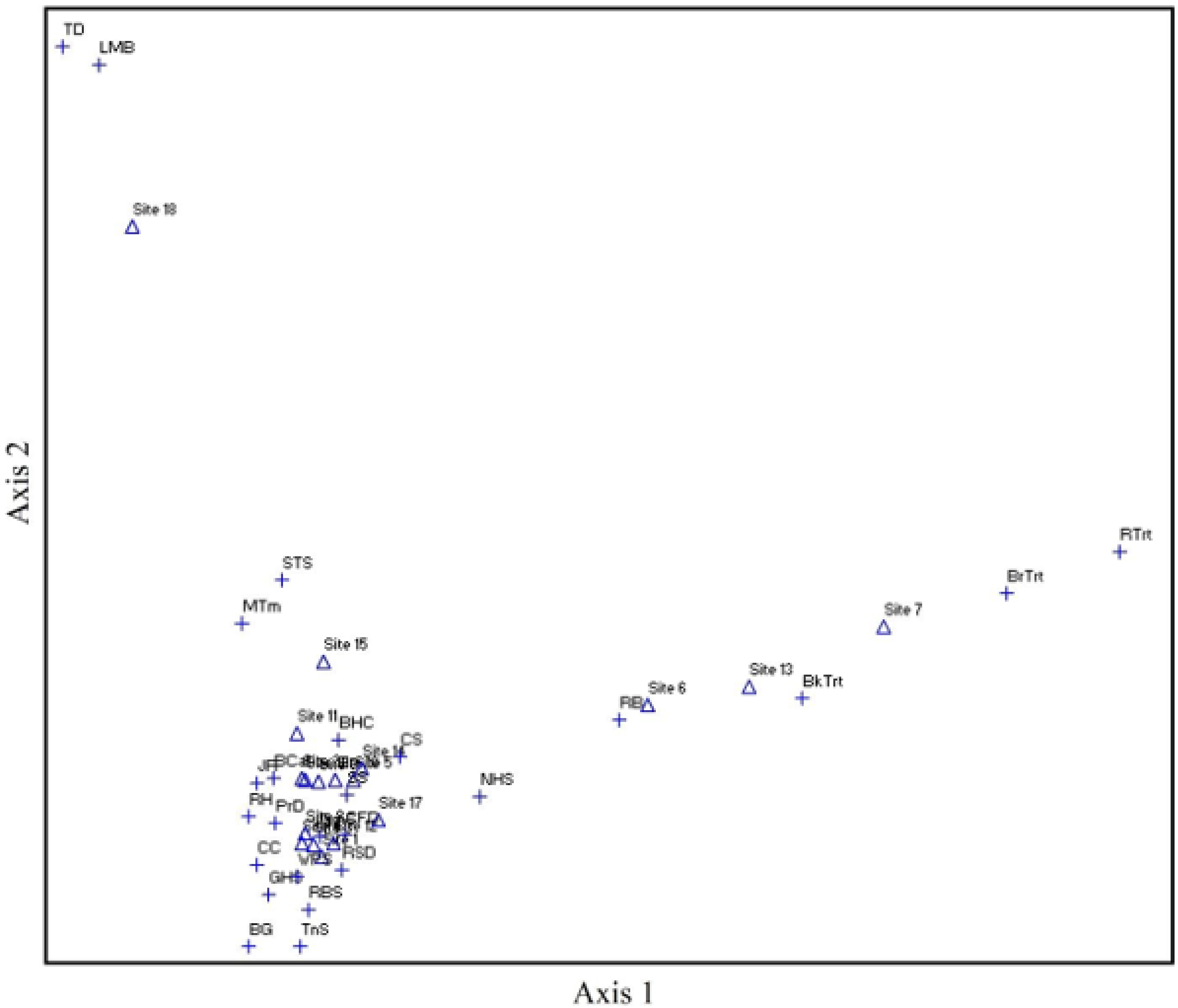

Figure 5. Correspondence analysis scores across all sites and fish species, triangles represent sites and crosses represent fish species, Axis scores represent standard deviations

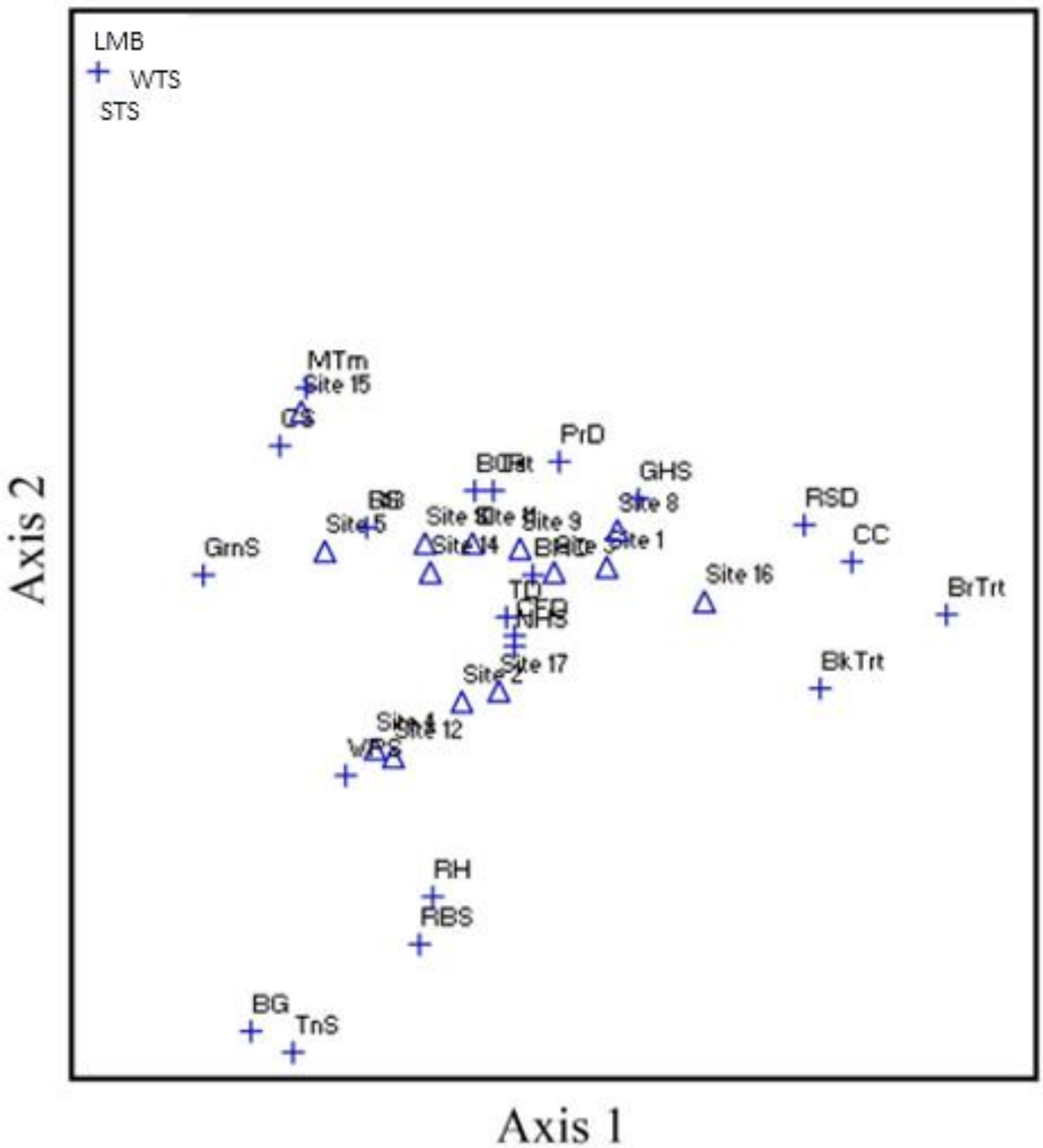

Figure 6. A correspondence analysis depicting the exclusion of outlier sites (7, 13, 6 and 18), Axis scores represent standard deviations

4. Discussion

This study indicated that habitat complexity has little influence on fish species diversity within the Lake James Watershed. When site habitat diversity indices were plotted with fish species diversity no correlation was found, suggesting that the availability of more habitat types does not support a greater amount of species. Similar results found by Gorman and Karr[2] describe the same lack of correlation in channelized, temperate streams, like those within this watershed. Additionally, when addressing habitat variable ranges for all fish species plenty of overlap was shown. This also suggests that little to no niche partitioning occurs in these streams, stressing the unimportance of habitat complexity.

There was also no indication that disturbance, measured by conductivity and land use data, plays a role in species diversity within the watershed. When analyzing the effects that urban/agricultural land use percentages and conductivity values has on species richness, no significance was shown. This suggests that fish species are not limited by the strength of disturbance in the form of water pollution. General tolerance of species found is also supported by the biotic index of fish species created by the NC Department of Environmental Quality[18]. The index lists only 4 of the 26 species found in this study as intolerant, two of which are *Oncorhynchus mykiss* and *Salvelinus fontinalis*, species frequently stocked year-round in many sites. Similarly, Meffee[13] found that intolerant species were eliminated from all sites potentially due to frequent and potentially historical abiotic disturbance patterns. However, since many of our sites had high species counts, most species being ranked as intermediately tolerant, and no outstandingly high conductivity values, this suggests a poor land use history within the watershed[19]. Land use information provided by the McDowell County Historical Society supports this claim, as they have described high rates of deforestation before the establishment of Pisgah National Forest (1916), along with long-term agricultural use and crop lands that are now converting to shrublands and forests. This information suggests that intolerant species were potentially eliminated decades prior to the study, leaving us with a group of tolerant fish that are relatively unaffected by varying amounts of disturbance.

Although there was no direct correlation between species richness and habitat complexity/disturbance, there did appear to be habitat variables that dictate the presence of certain species. Axis 1 showed the strongest negative correlation to temperature in both correspondence analyses. Other habitat variables played a more secondary role in determining the presence of certain species, made evident by the correspondence analysis without outliers. Water temperature trends on Axis 1 potentially distinguish which sites represent headwater streams. Sites six, seven, and 13 all show strong groupings with Salmonids, a headwaters family, and contain above-average large substrate composition and flow, while also having lower than average temperatures, variables that are indicative of headwater habitats. Site 18 was positioned as an outlier at the opposite end. This site (Paddy's Creek) was one of the lowest when considering altitude and was sampled very close to the lake indicating qualities of a stream lower in the watershed. Species that typically exist in lower reaches of watersheds, i.e. *Lepomis auritus* and *Lepomis macrochirus*, are both Centrarchids that show correlation to warm and deep waters based on their positioning on Axis 1 in the second correspondence analysis. Our results appear to draw similarities to Sheldon[7], a study which also concluded that environmental variables and fish species abundances change across higher and lower portions of watersheds. However, like in our study, environmental variables did not necessarily exclude many species because plenty of overlap still appears to exist.

Spatial patterns of fish species can also reveal information about watershed features. Fish community diversity within the Lake James Watershed appears to be unrelated to the complexity of habitat within streams. Additionally, disturbance from pollution was not a limiting factor for species in the watershed. Although habitat diversity didn't play a role in species diversity, there were habitat variables that affected the presence of some species, more specifically headwaters species, and appeared to show habitat variation along environmental gradients within streams. Our study may be useful because it shows how fish species organize themselves within the Lake James Watershed.

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