İSTANBUL UNIVERSITY PRESS

EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2023; 38(4): 189-193 • DOI: https://doi.org/10.26650/ASE20231285476

Research Article

Assessment of Lotic Macroinvertebrate Assemblage in the Oconaluftee River Basin in Cherokee, North Carolina

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Cite this article as: Benfield, S.B., & Unger, S.D.U. (2023). Assessment of lotic macroinvertebrate assemblage in the oconaluftee river basin in cherokee, North Carolina. *Aquatic Sciences and Engineering, 38(4)*, 189-193. DOI: https://doi.org/10.26650/ASE20231285476

ABSTRACT

Macroinvertebrate assemblage assessments act as useful analysis tools for assessing aquatic ecosystems health. These animals also serve as a base trophic level, acting as a source of food for many other aquatic organisms including fish and salamanders. Obtaining baseline data for monitoring aquatic insects and subsequent river health is vital to understand food chains and river ecological interactions. We sampled macroinvertebrate communities in two streams in the Oconaluftee River basin, in the Cherokee Qualla, North Carolina. Over 600 macroinvertebrates were collected and identified to the lowest taxonomic level possible, providing a macroinvertebrate profile of both riffle and run habitats. We identified over 35 genera and report on functional feeding groups, with biotic indices of water quality. Ephemeroptera, Plecoptera, and Trichoptera values varied, 21% and 65.43% for Raven's Fork and 22% and 79.06% for the Oconaluftee rivers. This macroinvertebrate community suggests healthy stream aquatic insects and above average water quality, in spite of the urban land use found in the riparian zones of the sample sites. This research can be used as a baseline for future monitoring of aquatic streams in the area of the Cherokee Qualla.

Keywords: Aquatic insects, freshwater biology, water quality, biological surveys

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Submitted:
18.04.2023

Revision Requested:
07.07.2023

Last Revision Received:
09.07.2023

Accepted:
10.07.2023

Online Published:
09.10.2023

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INTRODUCTION

Among the many threats to freshwater ecosystems, anthropogenic habitat loss and degradation have among the most visible and well documented impacts to biodiversity (Prakash & Verma, 2022). Aquatic insects can provide baseline data and act as early indicators of biotic change due to anthropogenic changes, as they are sensitive to fluctuations in water quality (Ghani et al., 2016). As human populations continue to increase, and potentially encroach more on protected areas, the potential to impact riparian communities, such as streams, may increase. Moreover, the reliance on water resources for future management requires baseline data on biodiversity so that monitoring efforts have comparative data to observe any changes in stream health.

Appalachian streams of the United States house a diverse array of aquatic predators which play integral parts in native food webs, and in North Carolina include recreationally important species of native brook trout, *Salvelinus fontinalis*, introduced brown trout, *Salmo trutta*, and introduced rainbow trout, *Oncorhynchus mykiss* (Rhode et al., 1994; Flebbe & Dolloff, 1995). However, the presence of trout can have a varying effect on the trophic dynamics in streams, including decreases in the proportion of grazers (such as mayfly species densities) within the functional feeding groups (Meissner & Muotka, 2006). Moreover, many trout species seasonally shift their diet according to time of year depending on the availability of aquatic insect groups (Hubert & Rhodes, 1989) or even

time of day (Giroux et al., 2000). Non-native trout introduced in streams can also indirectly alter total macroinvertebrate biomass by selecting larger individuals and consuming shredder and scraper functional feeding groups at a higher rate than others (Buria et al., 2007). Both the diversity and relative abundance of stream macroinvertebrates can vary by habitat type (either riffles, runs, or pools) sampled by researchers (Logan & Brooker, 1983). In addition, many studies which assess stream water quality and stream health quantify macroinvertebrate communities using only timed dip net surveys of riffles and do not account for surface area using Surber sampling, which may provide benefits to understanding macroinvertebrate structure by allowing researchers to estimate abundance per area across habitats.

The objectives of this study were to 1) characterize the aquatic insect abundance (Ephemeroptera, Plecoptera, and Trichoptera presence and distribution, indicators of stream health, and ecological importance of insect groupings of trout streams on the Cherokee Qualla (reservation) and 2) report on the potential role many of these aquatic insects have in food webs of Appalachia. These findings provide baseline biodiversity data on the overall stream health and also quantify potential macroinvertebrate prey of aquatic predators in these streams in North Carolina, including trout and other stream vertebrates.

MATERIALS AND METHODS

Study Locations and Aquatic Insect Identification

Samples were obtained from two streams in the Oconaluftee River watershed (Oconaluftee and Raven's Fork) of Cherokee, North Carolina in May of 2016. Stream locations sampled were categorized into two broad level habitat types, and the containers of organisms labelled with site location and area habitat type (riffle or run). Raven's Fork has been previously noted to be slightly acidic (pH of ~6.0) with low alkalinity during baseflow conditions (Armitage & Tennessen, 1984), whereas the Oconaluftee River has been documented to have a pH of 7.8 and Dissolved Oxygen of 6.6 ppm, and conductivity of 10 (Nickerson et al., 2022). We utilized more comprehensive sampling method (a Surber sampler: 0.3 meter X 0.3 meter metal frame placed above a collection net) to collect aquatic insects, with all stream locations being randomized for specific site of sampling. At each stream location, we sampled ten subsamples from both riffles and runs for aquatic insects and included at least three areas of at least fifty meters in length (Figure 1). Aquatic insect samples for each stream site were then combined as either a run or riffle habitat for that stream sample location to collect data for comparisons. Following each sample collection, all the area within the sampler was checked for any remaining aquatic insects and all rock substrate within the sample area was checked for additional aquatic insects, and these were included into our samples using fine forceps and careful inspection of sample net. Aquatic insects from sample habitats were stored in ninety-five percent ethanol. Identification, enumeration, and inventory of the collected samples was completed in the laboratory using standard dichotomous keys to identify all aquatic insects collected down to the lowest taxonomic level of genus within orders by both authors.

Data analysis

Several indices were selected to assess stream health based on the identified aquatic insect assemblages. Aquatic insects after identification were further placed into functional groups to inform stream health indicators, and we used the standard approach of placing insects into categories of EPT, or insects within the Trichoptera, Plecoptera, or Ephemeroptera orders were combined and analyzed across habitat types and stream locations. We compared numbers of EPT between our two sample streams using a Chi square analysis with our significance value as 0.05. Both the Hilsenhoff, Shannon diversity, Beta diversity, and Dominance indexes were calculated for all sample rivers. Aquatic insects were also placed into various categories (feeding function groupings), to examine the potential these aquatic insects have not only for water quality, but also for food webs or in the riverine food chain.

RESULTS AND DISCUSSION

In sum from the macroinvertebrate samples of both streams (Oconaluftee and Raven's Fork) and microhabitat types (riffle and runs), over 600 individuals were identified across 36 taxa belonging to 28 families (Table 1). Macroinvertebrates from the sampled Cherokee streams exhibited a broad range of functional feeding groups, with relatively high concentrations of gatherers in both streams (28.61% in the Oconaluftee and 27.14% in Raven's Fork) (Table 4). Both streams sampled for aquatic insects were characterized as having high biodiversity categories using the diversity indexes (Table 2). Moreover, both river locations were ranked high for river quality using the percent Ephemeroptera Plecoptera and Trichoptera method (Table 3). The Oconaluftee had a high ranking or percentage of Ephemeroptera, Plecoptera, and Trichoptera, approximately eighty-five percent in the runs and just over seventy-nine percent overall. These high scores were closely followed by Raven's Fork sample river, with an overall percentage of sixty-nine Ephemeroptera, Plecoptera, and Trichoptera, which was higher in the runs than in the riffles in both sampled streams, which is especially interesting as the runs are not usually sampled for macroinvertebrates and are often assumed to have low densities of sensitive insect taxa. There was not a significant difference between Ephemeroptera, Plecoptera, and Trichoptera combined taxa between our two sample locations, X^2 (2, N = 444) = 1.877, p =0.391, indicating both likely house di-

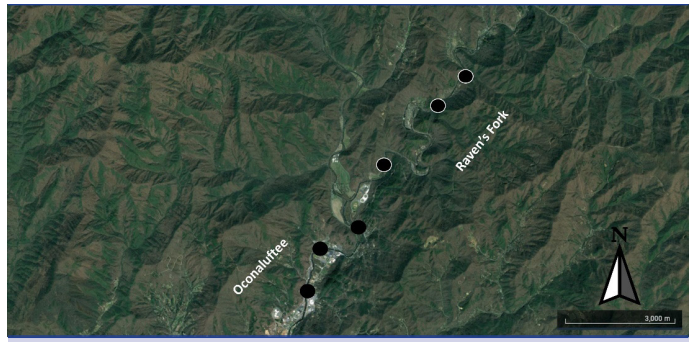

Figure 1. Map of Sample Locations for Oconaluftee (black borders) and Raven's Fork (white borders), North Carolina.

Table 1. Cherokee Qualla aquatic insect community richness and relative abundance sampled from the Oconaluftee and Raven's Fork rivers.

Order:Family	Genus:Species	Oconaluftee	Raven's Fork	Total
Coleoptera				
Elmidae	*Acryronyx sp.*	-	2	2
Psephinidae	*Psephenus sp.*	9	4	13
Ptilodactylidae	*Anchytarsus bicolor*	-	3	3
Diptera				
Chironomidae	*Paramerina sp.*	34	13	47
Ceratopogonidae	*Dasyhelea sp.*	4	3	7
Simuliidae	*Greniera sp.*	19	51	70
Tipulidae	*Tipula sp.*	-	3	3
	Leptotarsus sp.	1	9	10
Emphemeroptera				
Baetidae	*Baetis sp.*	3	-	3
Ephemerellidae	*Eurylophella sp.*	26	18	44
	Dannella sp.	22	1	23
Heptageniidae	*Maccafertium sp.*	2	2	4
Isonychidae	*Isonychia sp.*	13	8	21
Leptohyphidae	*Homoleptohyphes sp.*	30	6	36
	Hydrosmilodon sp.	24	9	33
	Leptohyphes sp.	15	35	50
	Tichorythodes sp.	-	3	3
Neophemeridae	*Neophemera sp.*	44	27	71
Polymitarcyidae	*Tortopus sp.*	1	-	1
Odonata				
Gomphidae	*Progomphus sp.*	-	2	2
Plecoptera				
Perlidae	*Beloneuria sp.*	10	9	19
Perlolidae	*Isoperla sp.*	1	9	10
Peltoperlidae	*Viehoperla ada*	1	-	1
Pteronarcyidae	*Pteronarcys sp.*	7	-	7
Megaloptera				
Corydalidae	*Corydalus sp.*	4	-	4
Trichoptera				
Baraeidae	*Baraea sp.*	1	2	3
Goeridae	*Goerita sp.*	14	2	16
Hydropsychidae	*Hydropsyche sp.*	11	5	16
	Potamyia sp.	-	1	1
Hydroptilidae	*Stactobiella sp.*	1	1	2
Leptoceridae	*Leptocerus americanus*	1	-	1
Philopotamidae	*Chimara sp.*	-	4	4
	Dolophilodes sp.	23	9	32
Polycentropidae	*Nyctiophylax sp.*	-	1	1
	Phylocentropus sp.	13	21	34
Uenoidae	*Fattigia pele*	5	3	8
Total:		**339**	**266**	**605**

verse aquatic insect communities. Subsequently, both rivers exhibited a high percentage of gatherer feeding group organisms, with Raven's Fork river having more filterers (21.46%) and the Oconaluftee having more predators (17.99%), indicating some variation in ecosystem groupings of aquatic insects (Table 4).

The Dominance Index for Oconaluftee was 0.935, while the Dominance index for Raven's Fork was 0.917. The mean number of taxa for Oconaluftee was 12.11, whereas the mean number of taxa was 8.87 for Raven's Fork. Beta Diversity Index between sites was 0.759, with 36 total taxa identified comprising of 28 taxa for Oconaluftee and 30 for Raven's Fork, with 22 shared, common taxa (found in both streams).

This work provides a water quality assessment and aquatic insect biodiversity survey for streams of the Cherokee Qualla, North Carolina. The data reported here indicate that streams in this geographic area have relatively high levels of aquatic insect biodiversity with taxa functioning across an array of ecological feeding groupings, likely due to the river's proximity to protected forests and the extensive efforts of the tribal community to preserve riverine health. These streams lie within the Eastern Band of the Cherokee Qualla, and their headwaters originate in the Great Smoky Mountains National Park, which is protected. However, the watersheds do include a combination of developed, forest, and mixed riparian zones and access. In particular, the run habitats housed a large percentage of Ephemeroptera, Plectoptera and Trichoptera, in all cases larger percentages than the riffle habitats. This may be due to riffle habitats being more intrinsically difficult to sample or the potential for higher flowing water to result in a different overall community of aquatic insects present in faster flowing riffles. Subsequently, we report on a wide assortment of macroinvertebrates, which not only provide a variety of ecosystem services but also are likely a vital component of the riverine food web, providing connections for other aquatic organisms.

The aquatic communities of streams in North Carolina are often measurably affected by varying land use (urban, forested, or agricultural), with lower biotic indexes and low species richness in urban areas (Lenat & Crawford, 1994). The area of Cherokee North Carolina is historically characterized by increasing growth of tourism (Tooman, 1997) while geographically situated in close proximity to the Great Smoky Mountains National Park, which was farmed and logged prior to becoming a national park. Our sampling occurred near the developed town of Cherokee, North Carolina, yet yielded high % EPT and overall high water quality metrics. Moreover, our study is the first published quantitative assessment of macroinvertebrate communities on the Cherokee Qualla, as our research involved sampling multiple habitats, which can produce greater number of taxa per site (Lenat, 1988). Our results report similar observations of taxa compared to other studies from western North Carolina (Loch et al., 1996), albeit at high densities.

Knowledge on stream trophic webs is important for the conservation of any aquatic ecosystem, as these processes can be affected at various levels by many factors with differential impacts on specific taxa or overall survival or populations of macroinvertebrates, which are often sensitive to water chemistry or siltation changes. Many of these aquatic insects provide food for other aquatic organisms. Future work could assess the impact of predatory trout abundance on macroinvertebrate communities. Sampling the diet (trout gut contents) of both wild and native trout could also provide further information on food webs in this ecosystem. Previous studies in this area have indicated both rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) rely on a variety of available food items including terrestrial inputs, or allochthonous resources (Cada et al., 1987). The macroinvertebrate communities we observed as part of this research may provide additional food for not only fish species, but also larval salamanders, such as the eastern hellbender, *Cryptobranchus alleganiensis*, as adults are occasionally observed within this area (C. Hickman, unpublished data). Continued monitoring of the river habitat and macroinvertebrate communities of the Oconaluftee riparian areas of Cherokee should be conducted to ensure this area remains protected and harbors high overall stream biodiversity.

Table 2. Hilsenhoff (HBI) and Shannon Diversity Indexes (SDI) calculated for both sample rivers in this study.

River	SDI	HBI
Oconaluftee	2.887	3.79
Raven's Fork	2.861	4.51

Table 3. River health metrics of percent EPT aquatic insects across habitat types from samples collected from the Cherokee Qualla.

River	%Ephemeroptera	%Plecoptera	%Trichoptera	% EPT- Riffle	% EPT- Run	% EPT-Stream	EPT Richness Index
Oconaluftee	53.39	5.60	20.06	74.88	85.29	79.06	22
Raven's Fork	40.52	6.69	18.22	58.99	78.02	65.43	21

Table 4. Ecological feeding groupings for aquatic insects from rivers in the Cherokee Qualla.

Functional Group	% shredders	% scrapers	% filterers	% gatherers	% predators
Oconaluftee	0.00	3.24	15.63	28.61	17.99
Raven's Fork	1.12	2.23	24.16	27.14	11.90

CONCLUSION

With this study, we utilized a Surber Sampler to assess benthic aquatic insects as potential indicators of stream health in an area of the United States that is highly visited by recreationalists, tourists, and has significant cultural influence to the Eastern Band of the Cherokee Indians. We hope this macroinvertebrate survey can provide a baseline of diversity and functional feeding group estimates for future monitoring, as well as illustrate the importance of sampling with more than a dip net across an array of in-stream habitats. Sampling in both runs and riffles also appears to be informative, as we noted differences between these two habitats across our sample locations. Protecting water resources is a vital component of management of aquatic habitats. Future research should be undertaken to monitor changes in these parameters within this unique watershed as the surrounding community continues to likely increase in population. Further sampling of water chemistry and other land use parameters could be used to help determine ideal locations for watershed protection to manage this system as efficiently as possible to maintain ecological food web connections to other inhabitants such as trout, hellbender salamanders, river otters, and other fish species.

Conflict of interests: The authors have no conflict of interest.

Ethics committee approval: Ethics committee approval was not needed. Permits for surveys were obtained from NCWRC, permit # 17-ES00286.

Financial disclosure: The authors have no financial disclosure to report.

Acknowledgements: We thank the Eastern Band of the Cherokee Indians for permitting, access, and information on aquatic communities. Wingate University provided funding for this research as an undergraduate research project. Protocols followed the Wingate Research Review Board.

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