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Longitudinal Zonation and Functional Feeding Groups of Western North Carolina Fishes

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Abstract

The variation in fish assemblage structure from high to low elevations was observed in two rivers within the French Broad River Basin, Swannanoa River and Little River. The Little River is less disturbed than the Swannanoa River, as the Swannanoa has greater development around it. I hypothesized that the headwater streams of the two rivers would possess smaller, less diverse assemblages of species and functional feeding groups than at lower elevations. I took samples of fish using a Backpack Electrofisher, taking them from riffles and pools at five sites along each stream, starting at the headwaters and ending near the tail waters for a ten-day period in June 2017. The number of species and functional feeding groups increased as the river sites decreased in elevation, as did the number of individuals per feeding group. This displayed a case of longitudinal replacement, which could serve as a model for predicting where certain fish species can be found in greater abundance in future studies. Both rivers surprisingly had the same number of species. The most abundant species found in both the Swannanoa and the Little Rivers was the Mottled Sculpin (17.4% and 15.6% respectively). The Swannanoa River ended up having all seven of the functional groups within its lowest elevation, whereas the Little River's only had six. This difference indicates that the Swannanoa has a slightly greater capacity for supporting more niches than the Little River, due to its larger size, which may provide a buffer against development.

1. Introduction

The biodiversity of an area depends on the amount of available niches that the habitat can support. This is true in freshwater stream habitats, where the size and geographical location can have great affect on the number of niches. This relates to the idea of stream orders where smaller orders are high in elevation and have a limited number of niches available [1]. As the stream order increases, the streams become larger, are lower in elevation, and because of their increased size can support more niches. This equates to more fish species for the stream, increasing biodiversity [2]. The increase in fish species as the river's elevation decreases is directly related to the river continuum concept, which states that fish species diversity and feeding group number will increase as the river runs from its headwaters to its mouth [3, 13].

North America supports the highest diversity of non-tropical fish species on the planet, with over 1200 species. The majority of these species dwell within rivers and lakes of the southeastern USA, specifically in the Appalachian mountain range [4]. Fish diversity here is higher than the rest of the USA, due to its plethora of mountain streams, which can cause geographical or allopatric speciation, and due to the Mississippi River basin being a glacial refuge during the height of the last ice age [1, 5]. Fish were able to migrate south during this time to escape glaciation, taking refuge in the rivers of this area.

An important component of fish diversity is the range of functional feeding groups within a fish community [1]. These are a series of categories that fish species are grouped into based upon how and what they consume, and where they may be located based upon their diet. The category of benthic pickers for instance feed entirely on aquatic macro invertebrates. Sitting along the river bottom, they will wait until food particulates or insects come floating by, then will swim up and snatch the food. Grazers meanwhile eat algae, which is mostly attached to pebbles of the river bottom[1]. The genus *Campostoma* is among the most common of grazers. Surface feeders swim mostly in the upper levels, looking for food floating upon the water's surface. The eyes and mouths of these surface feeders are turned towards the surface, so as to find and obtain food with greater ease. Drift feeders are fish that have among the most general of diets, eating foods both at the top and bottom of the water column. The genus' *Nocomis* and *Semotilus* are among the most common of drift feeders in western North Carolina streams. The mouths of gravel disturbers are turned downwards like the grazing fish, but protrude outward slightly more. They feed on detritus and benthic invertebrates between the gravel and pebbles at the river bottom – hence the name 'gravel disturbers.' Meat scavengers eat the decaying matter of other animals, and can often grow quite large. Catfish are some of the best known in this functional feeding group, consuming whatever is dead upon the river bottom. Benthic drift feeders consume food that is either on the bottom or floating near the lower areas of the water column, generally having a mouth centered or slightly lower down on the head. Functional feeding groups are related to an organism's niche, which is the biotic location of an organism within an ecosystem. Specifically it pertains to what and how the animal eats, and what eats the animal [10]. When relating this back to the larger community, a headwater stream can support only a few niches, whereas a larger stream at lower elevation can support a greater number of niches, therefore the number of functional groups increases too [3].

The purpose of this research study was to examine the relationship between fish community biodiversity and the elevation of the habitat, where streams located at lower elevations possess greater fish biodiversity than smaller, higher elevation streams. The study was divided between two watersheds in the Asheville area, the Swannanoa River and the Little River watersheds. The Swannanoa River runs through largely residential and urban areas, which would expose it to greater levels of polluted runoff. The Little River is located between the towns of Brevard and Hendersonville, in a greater rural landscape that has much less exposure to urban runoff. Land use practices differ between the two watersheds. Rashleigh et al (2004) found that the Little River was covered 96% by forest, 2% by agricultural land and 0.30% by urban development. The Swannanoa in contrast was covered 86% by forest, 6% by agricultural land and 7% by urban development. It would be reasonable then to expect the Little River would have a less disturbed watershed than the Swannanoa River [12].

Table 1. Elevations of River Sites Studied

	Swannanoa River (Highest -> Lowest sites)				
	Site 1	Site 2	Site 3	Site 4	Site 5
Elevation (Feet)	2835	2485	2333	2129	1979
	Little River (Highest -> lowest sites)				
	Site 1	Site 2	Site 3	Site 4	Site 5
Elevation (Feet)	2159	2105	2104	2092	2083

2. Methods

The methods were divided into studying both the fish assemblages of streams in and around the Asheville area. For both the Swannanoa and Little River, five sites were chosen, ranging from accessible upstream to downstream areas in order to get an equal variety of habitat. There were five sites studied along the Swannanoa River and four sites along the Little River. In order to record the data of the final site, as it was located in an area where sampling accessibility was limited, had to be taken from a past study in 2002 where one of the sample sites was this same location. At each site a single riffle and a single pool were chosen for sampling. The downstream sites had pools and riffles that were easier to choose, as there was more of a definitive boundary between the two. The upstream sites had a series of miniature pools and miniature riffles, which meant that each riffle and pool group had to be made up of two to three smaller riffles and pools respectively. First the length of the chosen riffle and pool were recorded using a habitat measuring tape. The riffle and pool boundaries were marked out with flags to give us an idea of where to sample for fish and habitat. The reason behind choosing riffles and pools for the habitat types stems from streams being made up of a pattern of the two habitat types (Riffle → pool → riffle → pool) [6]. These two habitats can provide benefits to fish living in them. Riffles can serve as safe locations where smaller fish will not be preyed upon by larger predators that have too large a body size to physically fit in such shallow water. Riffles serve too as a highway, where fish can rapidly move downstream or upstream in search of food. Pools serve a great purpose, more so for larger bodied fish. A pool can act as a hiding area from larger terrestrial, aquatic or aerial predators. The mouth of a riffle flowing into a pool acts as an excellent conveyor of food, where invertebrates, organic particulates and small fish are washed down directly towards large bodied predators [7]. Then measurements of water quality were taken within each riffle and pool at the site, recording average temperature, conductivity, dissolved oxygen and turbidity. These measurements were taken using the Global flow probe at 60% depth, no matter how shallow the water column was.

Next the fish populations were sampled using a Backpack Electrofisher, slowly moving upstream with the shocker in front and one to two netters directly behind to collect stunned fishes. Collected fishes were placed into a bucket for later recording. The number of individuals per species in both the riffle and the pool sections were recorded at each site. The fishes were returned to the stream after sampling was complete.

After field research was completed, the fish were grouped according to their functional groups. Using the book *Patterns in Freshwater Fish Ecology* [1], each species was grouped according to what how it consumed its food. Depending on where the sampling was taking place, there was an expectation to find more of certain functional feeding groups – upstream sites would have a greater abundance of benthic pickers since their habitat preferred habitat of riffles are the dominant habitat type in higher elevation sites, while downstream sites would have a greater abundance of drift feeders and gravel disturbers which relay on pools that coalesce the food they consume. A northern hog sucker (*Hypentilum nigricans*) prefers pools since edible detritus is more likely to settle in its lower flow center than a fast flowing riffle, while a Swannanoa darter (*Etheostoma swannanoa*) consuming food particulates is better able to see their target and consume it in a shallow riffle habitat.

3. Results

The total number of fish that I collected from the Swannanoa River was 293 individual fishes and 24 species. The Little River study sites yielded 270 individual fishes and 24 species. Overall fish species diversity increased as the site elevation decreased, with the Swannanoa River gaining up to 9 additional species at the lowest elevation site. The Little River gained 11 new species as the site elevations decreased (Figure 1). The top three species found in the Swannanoa River were the mottled sculpin (*Cottus bairdii*), the western blacknose dace (*Rhinichthys obtusus*), and the river chub (*Nocomis micropogon*) as seen in Table 1. The top three species found in the Little River were the mottled sculpin; redline darter (*Etheostoma rufilineatum*), and the Tennessee Shiner (*Notropis leuciodus*). In terms of functional feeding groups, both the Swannanoa and Little River sites had a majority of benthic pickers found in the higher elevations, but as the site elevation decreased, the numbers of the other feeding groups increased and evened out the diversity. Feeding guilds such as the drift feeders, gravel disturbers or grazers became more abundant downstream, mostly due to their preference for pool habitat, which provides greater amounts of food for them (Figures 2 and 3). Due to the greater habitat variety found in downstream sites, there are a greater number of niches that can support more functional feeding groups [1]. Between the two rivers, there were several species that were found only in one or the other. The whitetail shiner (*Cyprinilla galactura*), flat bullhead (*Ameiurus platycephalus)*, green sunfish (*Lepomis cyanellus*) and river redhorse (*Moxostoma carinatum*) were found only in the Swannanoa River. Saffron shiners (*Notropis rubricroceus*), banded darters (*Etheostoma zonale*), golden redhorse (*Moxostoma erythrurum*) and bigeye chub (*Hybopsis amblops*) were found only in the Little River (Table 2).

Table 2. Fish Species Percent Assemblage of Selected Rivers

	% Assemblage Composition	
Species	Swannanoa River	Little River
Mottled Sculpin (*Cottus bairdii*)	17.4	15.6
Blacknose Dace (*Rhinichthes obtusus*)	12.6	1.9
River Chub (*Nocomis micropogon*)	11.6	8.5
Redline Darter (*Etheostoma rufilineatum*)	9.9	14.7
Central Stoneroller (*Campostoma anomalum*)	9.6	5.2
Fantail Darter (*Etheostoma flabellare*)	7.8	5.6
Rosyside Dace (*Clinostomus funduloides*)	4.8	1.5
Redbreast Sunfish (*Lepomis auritus*)	4.4	3.7
Tennessee Shiner (*Notropis leuciodus*)	3.1	11.9
Bluegill (*Lepomis macrochirus)*	2.7	2.6
Northern Hogsucker (*Hypentelium nigricans*)	2.0	2.6
Rainbow Trout (*Oncorhychus mykiss*)	1.7	0.7
Greenside Darter (*Etheostoma blennioides*)	1.0	2.0
Flat Bullhead (*Ameiurus platycephalus*)	1.0	0.0
Mirror Shiner (*Notropis spectrunculus*)	1.0	0.7
Warpaint Shiner (*Luxilus coccogenis*)	1.0	4.8
Green Sunfish (*Lepomis cyanellus*)	0.7	0.0
Creek Chub (*Semotilus atromaculatus*)	0.7	3.7
River Redhorse (*Moxostoma carinatum*)	0.7	0.0
Mountain Brook Lamprey (*Ichthyomyzon greeleyi*)	0.3	1.1
Whitetail Shiner (*Cyprinella galactura*)	0.3	0.0
Swannanoa Darter (*Etheostoma swannanoa*)	0.3	5.6
Gilt Darter (*Percina evides*)	0.3	7.0
Rock Bass (*Ambloplites rupestris*)	0.3	0.7
Saffron Shiner (*Notropis rubricroceus*)	0.0	4.4
Banded Darter (*Etheostoma zonale*)	0.0	1.1
Bigeye Chub (*Hybopsis amblops*)	0.0	0.7
Golden Redhorse (*Moxostoma erythrurum*)	0.0	2.2

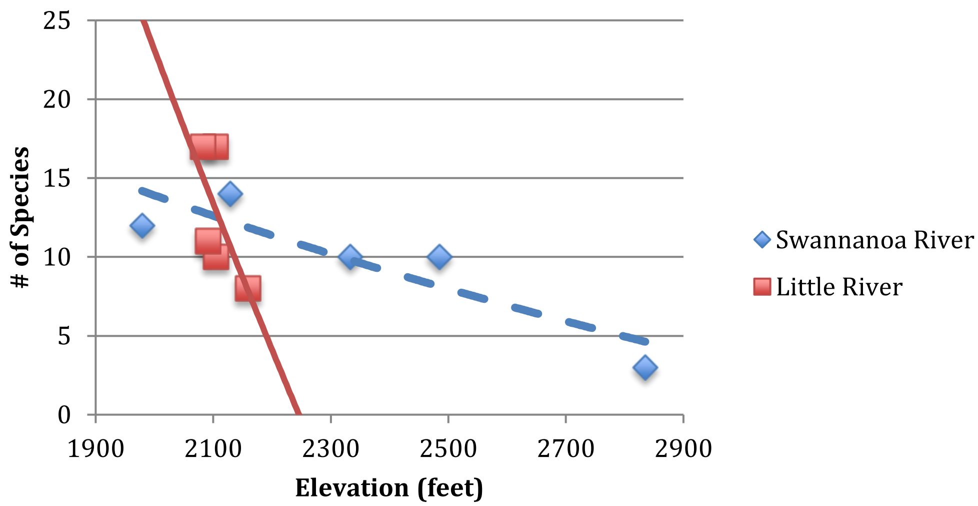

Figure 1. Relationship between site elevation and species richness found in the Swannanoa River and the Little River.

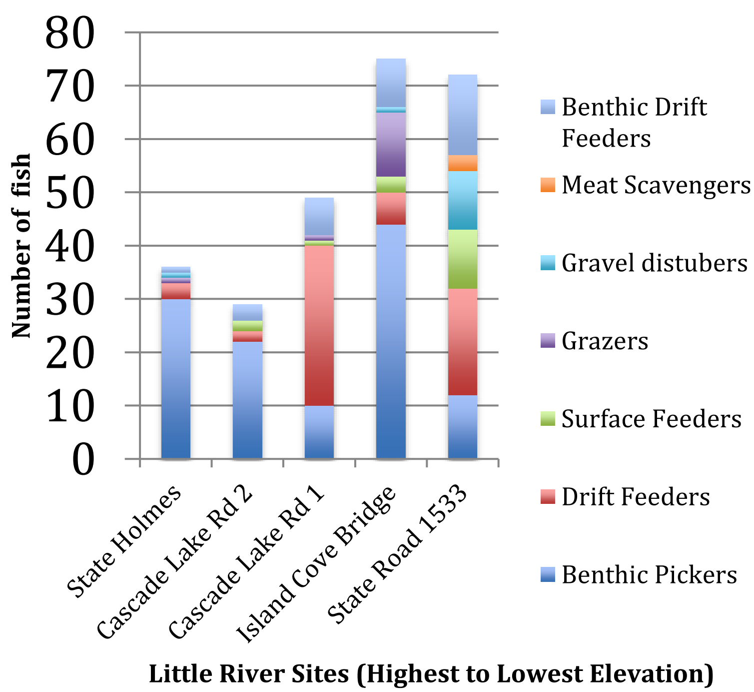

Figure 2. Number of individuals of each of seven functional feeding groups of Little River as designated by Matthews (1998).

Figure 2 illustrates how the headwater sites within the Little River watershed had fewer numbers of functional feeding groups than the lower elevation sites, as well as possessed fewer individuals per functional group. Cascade Lake Road for example had only four groups, and three of the groups had a maximum of three individuals per group (Drift feeders, Surface Feeders, Benthic Drift feeders). A low elevation site like State Road 1533 had six functional groups, and a larger number of individuals per group (20 drift feeders, 11 surface feeders, 15 benthic drift feeders).

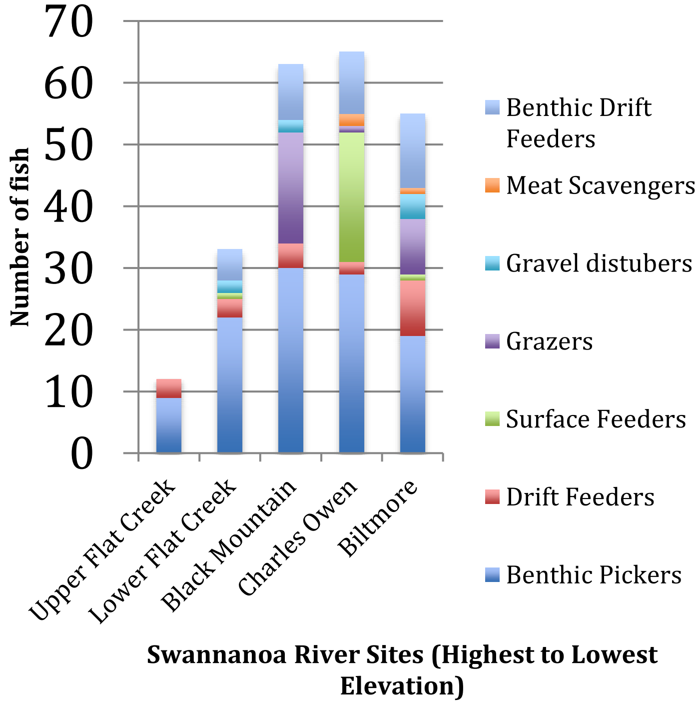

Figure 3. Functional Feeding Groups of Swannanoa River, as designated by Matthews (1998)

Figure 3 displays how stream sites of higher elevation within the Swannanoa watershed contained fewer functional feeding groups than the lower elevation stream sites, and more individuals per functional group as well. Upper Flat Creek site possessed only two functional groups (10 benthic pickers and 3 drift feeders), whereas a lower site like the Biltmore had all seven functional groups, and more individuals per group.

4. Discussion

The hypothesis for the likeliest outcome was that the amount of fish species would increase as the elevation of each consecutive site decreased. As mentioned in the results the hypothesis was supported, with both of the river systems selected for study following this trend. The increase in the number of species found is in direct correlation with the descent and enlarging of the river, since a larger stream is able to support a greater number of habitat niches [1]. The size of the rivers can influence the number of species as well, since a larger habitat will have a greater buffer size, allowing the ecosystem to support greater amounts of niches even with an increased level of development around the stream body [12]. The Swannanoa River being of larger area than the Little River can therefore support a greater number of niches and functional feeding groups because its very size provides a buffer against development's negative effects [5].

An unusual observation made during the study was the presence and/or absence of certain species from the Little River and the Swannanoa River. The Little River for instance lacked Flat Bullhead, Green Sunfish, Whitetail Shiners, and River Redhorse, whereas the Swannanoa possessed those species. The Swannanoa for its part did not contain several species which were found in the Little River, namely Saffron Shiners, Banded Darters, Bigeye Chub and Golden Redhorses.

Both river systems were identical when it came to what fish species was most abundant. The most populous species was the Mottled Sculpin. The Swannanoa River's second most abundant species was the River Chub, while the Little River's second most abundant species was the Redline Darter. The sculpin species however was found almost entirely in the high elevations, rarely if ever being found downstream. What was found almost entirely downstream were darters, which are in the same functional feeding group as sculpin. Sculpin are more territorial than darters and will outcompete them in the *benthic picker niche*, but cannot tolerate water temperatures above a certain temperature. Darters meanwhile can tolerate warmer waters and without the presence of the aggressive sculpins downstream are able to fulfill their niche successfully [11].

The biggest part of the study where there may be errors in the data would have to be when examining the results of the Little River's assemblage. The lowest elevation site data were obtained in 2002, 15 years prior to when my study was carried out. Originally the plan was to collect data at this location, but due to the inaccessibility and unknown depths of the river, it was impossible to sample here at the time of the study. It was unclear about how the river may have changed during that span of time, noticing that the lowest stream site had several species that had not occurred in the higher elevation sites. One such species was the golden redhorse, which made sense due to this species' preference for larger and deeper habitat than other stream fish [9].

While observing longitudinal zonation amongst the fish assemblages of the Swannanoa and Little River, future studies were discussed that would yield interesting results. One such study harkens back to the niche sharing between sculpins and darters. The sculpins were found largely upstream, while the darters occurred mostly downstream. It would be enlightening to determine where exactly the populations of both fish overlapped, to determine if water temperature or another habitat characteristic would influence the presence/absence of sculpins or darters. To continue the observations that were made on these two rivers over a longer period of time would certainly be beneficial to gaining an enriched understanding of the species assemblages of these two rivers. Comparing them with other rivers in the area would be interesting as well, since both the Little and the Swannanoa flow into the French Broad. Taking observations from the Davidson or the Big/Little Ivy Rivers would be enlightening, for these rivers may have completely different assemblage make ups.

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