Biotic Guild Diversity with Varying Stream Parameters

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Abstract

The River Continuum Concept is a model that provides a framework for predicting many characteristics of a river or stream based off of its order. We examined three streams, the Mississippi River headwaters, a creek emerging from Mark Lake, and a iron spring that flows into Elk Lake, all with varying characteristics, but all headwaters of a streams found within Itasca State Park, MN. Physical properties of each stream were measured along with an assessment of the stream's species richness found by looking at the richness of the biotic guilds of anuran, terrestrial invertebrates, benthic invertebrates, aquatic vegetation, emergent vegetation, and riparian vegetation. We found the Mississippi headwaters to have the highest species richness in all guilds but riparian vegetation, leading us to believe it to be a middle-order stream based of the characteristics described in the River Continuum Concept.

Introduction

Streams are classified in a continuous manner based on the changes in their physical and biotic characteristics In stream analysis, a measure of species richness can be used to classify stream order (Vannote et al., 1980). The stream system is continuous with a large amount of habitat heterogeneity as well as a land and water exchange. The diversity of the community both within the stream as well as outside of the stream within the riparian zone allows for an increase in the richness and the diversity of the vegetative, invertebrate, and anuran species within this ecosystem. The relationship between the river and its surroundings greatly influences the growth, distribution, and maintenance of the biodiversity within the system (Robinson et al., 2002). The fauna located in this ecosystem include both aquatic and terrestrial organisms. The specific biodiversity of the stream is greatly influenced by the presence of many factors that allow for optimal growth. These factors include but are not limited to: environmental gradients that provide a habitat for members of the species at all stages of their life cycle to thrive, routes for both migration and dispersal, strategic distribution of fauna, food resources, and places for shelter (Robinson et al., 2002). The diversity of the fauna is dependant upon these characteristics.

Anuran diversity can also be indicative of a stream order. Amphibians generally inhabit stream environments due to their cold temperature adaptation and presence of invertebrate species. Stream size greatly affects the species richness of an assemblage of frogs. Mid-range streams tend to support a greater number of frog species than do smaller stream (Welsh and Hodgson, 2008). Frogs that breed within streams require enough water to sustain the growth of their offspring throughout development. Larger streams also contain more water for a longer time, which may decrease mortality of young frogs due to dry-outs. Additionally, the surrounding vegetation is important to anuran diversity. The ground layer vegetation has a much larger impact than does the forest overstorey (Parris and McCarthy, 1999), because the surrounding vegetation influences the type of organic matter introduced into the stream, which in turn facilitates the growth of invertebrates and the detritus within the stream and increasing species diversity. The forest surrounding the stream ecosystem will also influence the terrestrial invertebrate diversity as well. A forest can hold many different habitats that increase species diversity.

MacArthur and Wilson's island biogeography model states that larger 'islands' should have higher species richness and diversity relative to smaller 'islands' (1967). The authors also further explain that this model can also be used for isolated ecosystems other than islands. Certain physical characteristics of streams can promote diversity among its inhabitants whether they are aquatic, terrestrial, vegetative, or animal.

Mississippi River, Mary Creek, and the Elk Lake iron spring are three bodies of water that exhibit different characteristics. The section of Mississippi River studied is the headwaters portion that flows out of Lake Itasca. Although this stream is considered a headwaters order, its characteristics are more closely aligned with those of a middle-order stream. A typical headwaters stream is very strongly influenced by riparian vegetation due to the shade cover it provides which limits productivity. A middle-order stream has a more limited amount of riparian vegetation that has a small effect on the productivity of the river and contributes less allochthonous detritus. There also should be a large amount of invertebrate diversity consisting of collectors, grazers, and shredders. Both Mary Creek and the Elk Lake spring can be considered first order streams. A large amount of shade cover should limit the productivity of these streams. Also, the diversity of this order of stream should be lower than that of a mid-order stream (Vannote et al., 1980). In our study we examined the diversity of biotic guilds in relation to the streams' physical characteristics such as width, depth, temperature, dissolved oxygen, and conductivity. We predict that the Mississippi Headwaters will have the highest species richness among biotic guilds due to its larger width and depth.

Methods

Three separate sites were sampled to measure diversity among biotic guilds in streams. Sample sites consisted of the Mississippi Stream, Mary Creek, and Elk Lake Spring. Aquatic, emergent and riparian vegetation, benthic and terrestrial invertebrates, anuran species and stream characteristics were sampled at each site. Riparian vegetation diversity was measured by counting the individual species of plants surrounding the stream where the invertebrates were sampled. Benthic invertebrate samples were collected using the D-net method where the benthic sediment of the stream was disrupted and organic matter was caught through a D-net several feet downstream from where the net was placed. The sediment obtained in the nets was placed in a sieve and sorted in the lab to determine the invertebrate species richness. Following the sorting of the invertebrates, each type of invertebrate species was grouped and counted. Terrestrial invertebrates were collected using sweep nets adjacent to the areas where the benthic samples were taken. These samples were later sorted and counted to obtain information about invertebrate species diversity using the Shannon-Weaver Diversity Index (H) equation: $H= -\sum p_i \ln(p_i)$ in which p_i is the proportional abundance of species i. Anuran diversity was counted using two methods. The first method involved searching for diversity near the sampled areas and recording the number of species and individual frogs present. Secondly frog calls were surveyed at 9:30pm on two nights to determine the species present. Temperature, dissolved oxygen, depth, width, and conductivity were measured at each stream using a YSI dissolved oxygen, temperature, and conductivity meter (Model No. 85-100 FT). Depth and width were found by taking measurements at three sites of the stream and finding their average.

Results

The three streams examined varied in their physical characteristics. The Mississippi Headwaters had the largest average width and depth of 7.28 m and 0.34 m, respectively and the highest temperature of 21.1°C and dissolved oxygen of 9.36 µg/L (**Table 1**). The Elk Lake Spring was the smallest of the three streams with a width of 1.63 m and a depth of 0.06 m, and also a high conductivity of µS and low temperature of 8.0°C **(Table 1)**. Mary Creek's physical characteristics were in between those of the Mississippi River and Elk Lake Spring except for dissolved oxygen which had a relatively low value of 1.29 µg/L.

Species richness was compared between the different biotic guilds. The Mississippi River contained the highest species richness in all guilds except riparian vegetation (**Figure 1**). Species richness was especially high for the Mississippi terrestrial invertebrates with 50 distinct species. There was no emergent or aquatic vegetation observed in Mary Creek, but it contained the highest species richness among riparian vegetation. The Elk Lake Spring contained no aquatic vegetation and relatively low benthic invertebrates with only two species found **(Figure 1)**. Anuran species richness was twice as high in the Mississippi River when compared to Mary Creek and Elk Lake Spring **(Figure 1)**. The Mississippi River showed the highest emergent and aquatic vegetation species richness, but the lowest riparian vegetation of the three streams **(Figure 1)**.

To further analyze diversity of the three streams, the diversity index of benthic invertebrates was evaluated. The Mississippi River and Mary Creek showed similar diversity indexes of 1.50 and 1.46, respectively (**Figure 2**). Elk Lake Spring exhibited a lower diversity index of 0.305.

Discussion

The Mississippi River had the highest biodiversity in the biotic guilds of frogs, benthic invertebrates, terrestrial invertebrates, emergent vegetation, and aquatic vegetation (**Figure 1**). These results may be due to an increased level of aquatic and emergent vegetation relative to Mary Creek and Elk Lake Spring is. The Mississippi Headwaters may be considered more of a middle-ordered stream, because of the relatively high biodiversity and its physical characteristics. Middle-ordered streams tend to have the highest aquatic diversity of all the stream orders, and decreased canopy cover (Vannote et. al., 1980). The Mississippi Headwaters may closely resemble a middle-ordered stream because it originates from a lake. The River Continuum Concept may not represent the stream accurately based on location or order alone, but can by explain parameters of a stream.

Although the Mississippi may have an overall higher biodiversity, closer analysis of the diversity index among benthic invertebrates shows the Mississippi and Mary Creek to have similar biodiversity index values (**Figure 2,Table 2**). One reason for this observed similarity may have been the high abundance of species 1 in the Mississippi River relative to all other species. This caused an overall decreased diversity index even though species richness was relatively high. Another special feature specific to Mary Creek is its high abundance of riparian vegetation **(Figure 1).** This is due to is locale being within a dense forest region, as opposed to the Mississippi River which is more open.

The Mississippi River and Mary Creek had benthic diversity indexes of 1.50 and 1.46 respectively, while Elk Lake Spring had a benthic diversity index of 0.30 (**Figure 2, Table 2**). We attribute this to its high conductivity of 570 µS which can be credited to the fact the stream is ground fed, with a high iron concentration. Terrestrial and aquatic animals have thresholds for various characteristics of their surroundings (Loxdale and Lushai, 1999). Elk Lake Spring has a high iron content that can be observed by its orange colored benthic zone. It also has a much lower average temperature at 8.0°C. These two factors could surely explain the low diversity of benthic invertebrates, but could also explain the relatively low richness of terrestrial invertebrates. Many insects require water for reproduction or developmental stages of their lives (Hagar and Saintours, 2008). If the water has too high of an iron concentration or too low of temperature it may not be suitable for a variety of insects species.

Results from our study provide support for our hypothesis that species richness of biotic guilds are highest in the Mississippi River. Frogs, terrestrial invertebrates, benthic invertebrates, emergent vegetation, and aquatic vegetation all show highest overall species richness within the Mississippi River. Riparian vegetation was the only biotic guild in which the Mississippi River did not show the greatest species richness. As stated earlier, the Mississippi is also more representative of a middle-ordered stream indicative of higher species diversity and richness.

Although our results are supportive of our hypothesis, statistical analysis was not possible due to complications in the field work and lab processing. Pooling of samples into one container made replicates impossible to separate terrestrial and benthic invertebrates. More quantitative measurement were sought after, however, due to lack of equipment and required permits we were obligated to rely on more primitive techniques. This technique made statistical analysis extremely difficult due to not having all variables constant. Different amounts of time and effort were concentrated on one stream more than the others.

Further work could be done in analyzing the biodiversity of biotic guilds other than benthic invertebrates. Separate replicate samples should be taken in order to allow for statistical testing of variables. If we had an extended period of time, benthic and terrestrial invertebrates could have been identified for genus and species. This would have allowed for correlation data between frog diversity and invertebrate diversity. The same process should be done for the three types of vegetation. More complex live trapping techniques should be used to ensure all species of frogs are accounted for.

In conclusion, our results are supporting of our hypothesis that richness of biotic guilds will be highest in the Mississippi River. However, many improvements to our sample collecting and processing techniques are needed to be made before future research. Specific anuran and invertebrate interactions could be looked at in more detail to provide insight on biotic communities. More specifically, predator-prey and resource-competition interactions should be examined to describe the inter-specific relationships.

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Stream	Temp (°C)	Dissolved Oxygen (ug/L)	Conductivity (µS)	Salinity (ppt)	Width (m)	Depth (m)
Mississippi Headwaters	21.1	9.36	321.3	0.2	7.28	0.34
Mary Creek	14.3	1.29	435.6	0.2	1.63	0.16
Elk Lake Stream	8	7.59	570	0.3	0.30	0.06

Table 1. Shows the various physical characteristics of the Mississippi Headwaters, Mary Creek, and Elk Lake Spring.

Species	Mississippi Pool	Mississippi Riffle	Mississippi Average	Mary Creek	Elk Lake Spring
Species 1	23	212	117.5	3	0
Species 2	17	15	16	1	0
Species 3	10	18	14	8	0
Species 4	3	14	8.5	0	0
Species 5	27	16	21.5	2	10
Species 6	1	34	17.5	60	0
Species 7	1	2	1.5	0	0
Species 8	1	3	2	5	0
Species 9	2	3	2.5	6	0
Species 10	2	0	1	5	0
Species 11	1	0	0.5	5	0
Species 12	0	0	0	1	0
Species 13	1	0	0.5	0	0
Species 14	0	0	0	1	0
Species 15	2	0	1	0	0
Species 16	0	0	0	0	1
Total	**91**	**317**	**204**	**97**	**11**
Species Richness	**13**	**9**	**13**	**11**	**2**
Diversity Index	**1.88**	**1.22**	**1.5**	**1.46**	**0.3**

Table 2. Shows the total number of species, species richness, and diversity index of the different streams.

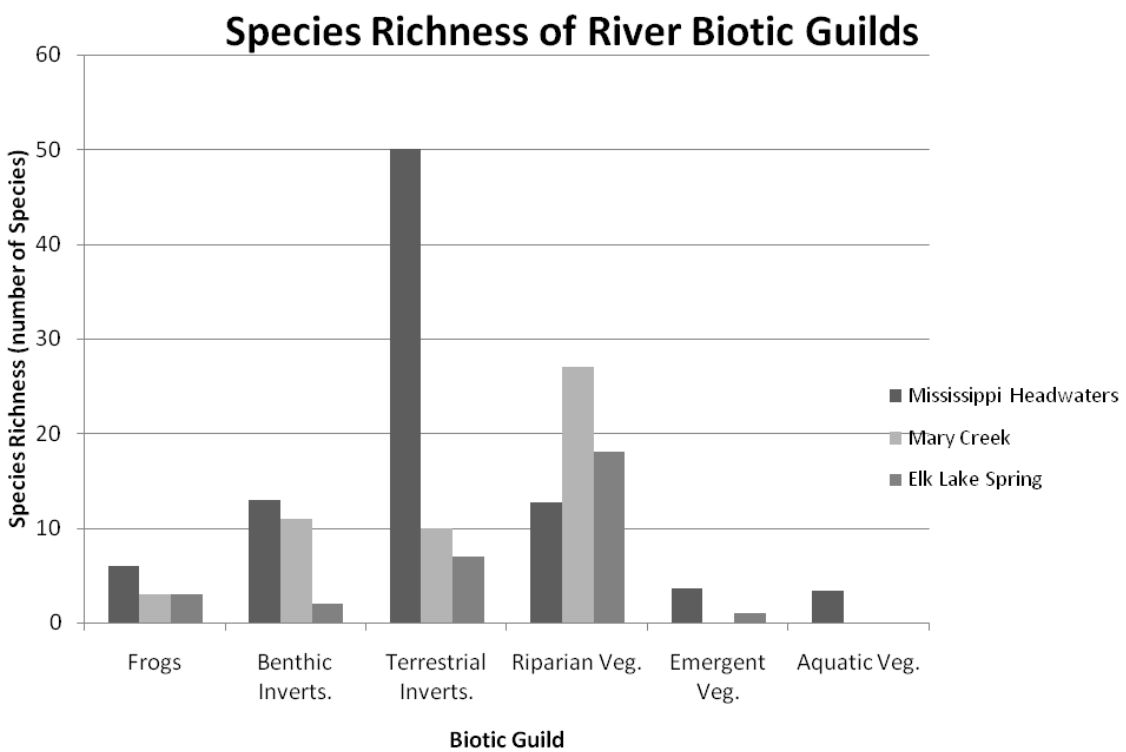

Figure 1. Shows the species richness of the various biotic guilds studied within the Mississippi Headwaters, Mary Creek, and Elk Lake Spring.

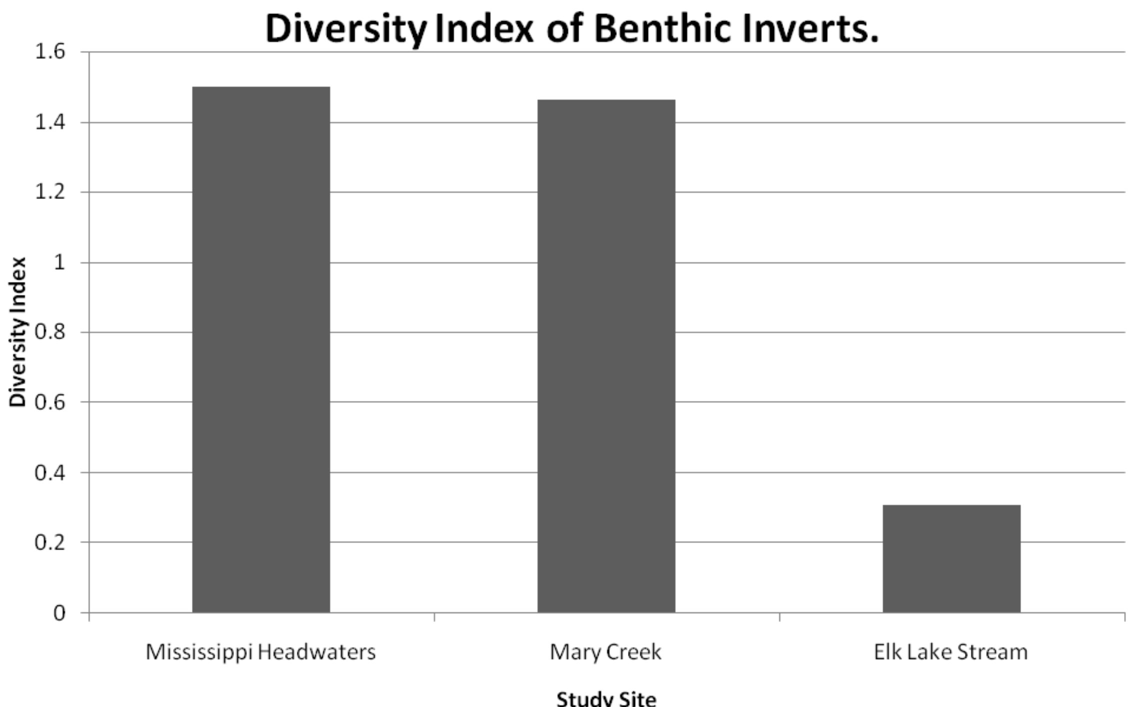

Figure 2. Shows the diversity index of benthic invertebrates within the three streams being studied. All areas sampled were near the source of the streams. The index value for the Mississippi Headwaters, Mary Creek, and Elk Lake Stream were 1.50, 1.46, and 0.305 respectively.