Comparison of Two Small Streams in Itasca State Park with the River Continuum Concept

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Ecology 3807, Summer 2008

Abstract:

The river continuum concept (RCC) first proposed by Vannote et al. (1980) has widely been accepted as the general template for characterizing the ecology of streams and rivers as water travels from the headwaters to much larger bodies of water. We tested the RCC on two small streams, Mary Creek and Chambers Creek in Itasca State Park. The streams chosen were both small with lentic sources, however physically the streams differ greatly in the variables we examined. We examined variables including substrate type, flow, canopy coverage, depth, width, pH and macro-invertebrate functional feeding groups to test if the two streams would fit the concept of low order streams. We found that the two streams are significantly different from each other and that Chambers varies somewhat from the RCC. Mary Creek fits the characteristics of a low order stream while Chambers Creek fits the physical characteristics of a mid order stream with some of the community composition of a low order stream. Mary Creek's characteristics that classify it as a low order stream are the almost complete canopy coverage, narrow average width of 2.5m, shallow depth of 19cm, and substrate of rock and sand. Whereas, the characteristics that make Chambers Creek a mid order stream are little to no canopy coverage, mid size width averaging 10m, depth of 70cm, and a substrate of silt and sand. The organic matter at each location also differs, Mary Creek is comprised of coarse particulate organic matter (CPOM) and Chambers Creek is comprised of mostly fine particulate organic matter (FPOM). This organic matter is the primary nutrient source for different functional feeding groups.

Introduction:

River systems are conceptualized as a continuum of biotic and abiotic conditions of an understandable pattern (Roper & Scarnecchia 2001). From the headwaters to the mouth of the river, the physical variables of the system make a continuous gradient of physical conditions (Figure 1., Vannote et al. 1980). This gradient creates different responses from the living populations that result in a continuum of adjustments along the river. Streams are divided into order depending upon size. Headwaters and small streams are grouped as order 1-3, medium sized streams are groups as order 4-6, and large rivers are grouped as order >6 (Vannote et al. 1980). The biotic components of these streams have various functional groups such as producers, consumers and decomposers. The types and abundance of functional feeding groups and species present in streams depends upon the order of the stream and its physical components. The RCC predicts that variation in functional feeding groups will be seen as the size of the stream increases. In streams of order 1-3, shredders are expected to be co-dominant with collectors, primarily consuming bacteria produced sugars off of CPOM, such as detritus, accumulated from the dense surrounding canopy. In order 4-6 streams canopy coverage is less dense due to greater width of the stream, resulting in an expectation of a larger temperature flux and the highest level of species diversity. It is also assumed that periphyton growth would be greatest at mid-order streams, resulting in the highest production to respiration ration due to the available light and relatively warm temperatures compared to streams of lesser or greater orders. Streams of orders >6 are assumed to be collector dominant, primarily feeding on fine and ultrafine particle organic matter that results from upstream inefficiencies (Vannote et al. 1980).

For our study we tested if the RCC applies to a low gradient, low elevation region like Mary Creek and Chambers Creek. The RCC assumes that the headwaters are high elevation and high gradient systems (Vannote et al. 1980). As the stream orders progress the RCC implies a decline in both elevation and gradient. Chambers Creek and Mary Creek are two streams located within Itasca State Park (Northwestern Minnesota). Both originate at the outlets of lakes, and would be classified as streams of order 1-3 according to the RCC (Vannote et al. 1980). Chambers Creek is a short, straight stream off of Elk Lake that connects to Lake Itasca and has virtually no canopy cover. Mary Creek is more narrow and meandering stream that begins at the outlet of Mary Lake and is almost completely shaded by the forest canopy. We expect that Mary Creek will conform well to the RCC as it fits into the physical description laid out by Vannote et al. (1980) almost perfectly given the width, depth, canopy coverage, and sediment type. We expect the invertebrate community for Mary Creek to be comprised mostly of shredders and collectors. For Chambers Creek we expect that it will not conform to the RCC because although it should be classified as a headwater stream (order 1-3) it has many qualities of a 4-6 order stream such as an open canopy and greater width and depth. We also expect that Chambers Creek will have a mid-order invertebrate community of collectors and grazers given the physical mid order characteristics.

Methods:

To assess different orders of streams in accordance to the RCC within Itasca State Park, stream vegetation and canopy coverage were used to identify the two test locations (Mary Creek and Chambers Creek). Once the canopy coverage had been assessed, 15 randomly numbered flags were placed every 3 meters along both selected test streams. Due to the environmental conditions, and the lack of proper equipment, there was no safe sampling method for the deeper regions of Chambers Creek. Therefore only the first 45m from the beginning of the creek were included in the sample area. The flags at Mary Creek were placed at the first fifteen riffle-pool systems from the start of the stream. Collection at both test locations took place at six sites, chosen randomly. At each selected site at Mary Creek, collections were taken from each riffle and pool, as well as recording the width of the stream between each sampled riffle-pool system. The largest depth and the width across at each sampled flag were also recorded during the collection. At Chambers Creek, the entire width of the stream at each selected site was sampled. Dip nets were used to scrape the riparian vegetation and stream bed of each sampling site, and then the contents of the net were examined in shallow pans. In addition, large rocks and logs found within each sampling site were taken from the water and examined on location.

All macro-invertebrates found during the sampling were preserved in vials of 70% ethanol and returned to the laboratory at the University of Minnesota's biological research station. In the laboratory, all collected samples were first divided identified to taxonomic order and then into functional feeding groups, according to Merritt et al. (2008).

In addition to stream width and depth, the dissolved oxygen content and temperature were measured at each sampled riffle-pool system using an YSI 85 Oxygen Salinity & Temperature probe. Current speed was also collected by timing the same leaf with a stopwatch traveling down the stream between the first two collection points at each test stream. In addition, two clay pots were placed at randomly chosen flags at both Mary and Chambers Creek, submerged laterally with the concave end facing upstream in order to collect periphyton biomass accumulated over the course of one week. However upon collection of these periphyton samples we discovered that the clay pots had been tampered with and periphyton analysis was not conducted. Substrate and water samples were also collected at each sampled site and brought back to the laboratory. Water samples were tested for average pH with a Corning 240 pH meter and substrate was examined and characterized.

Results:

The environments of both streams were assessed using quantitative measures for width, depth, current speed, and pH at each site. The average values were determined and analyzed using a t-test. We found that the width and depth of both sites were statistically significantly different ($t=31.515$, $df=11$, $p<0.001$ and $t=18.911$, $df=11$, $p<0.001$ respectively) (Table 1). Average pH was not significantly different between the two sites ($t=0.46$, $df=8$, $p>0.50$). Current speed was not measured as an average value, but was calculated over six meters at the mouth of each site. The current was determined to be different between the two sites with a percent difference calculation (percent difference=130.45%). The canopy cover and substrate were strikingly different enough that a true quantitative measure was not used in determining our classification of the stream order for each site.

A chi-square test was used to analyze the difference between the functional feeding groups sampled from each site (Fig. 2). The sites were found to be significantly different overall according to the data. A chi-square was also performed to analyze the composition of FFG's other than predators (fig. 3). The sites were still found to be significantly different. The periphyton growth data was inconclusive due to tampering with one of the clay pots.

The general taxonomic diversity of the orders of macro-invertebrates at each site was also cataloged (Table 2). At this level of identification the sites were found to be not statistically significantly different in the macro-invertebrate community composition (t=1.251, df=11 p=0.12), but at this level of certainty it is possible to draw some general conclusions.

Discussion:

We found significantly different physical characteristics between the two field sites. Mary Creek is significantly smaller than Chambers Creek which may contribute to a difference in functionality. Width and depth were statistically different between the two sites. The average width at Chambers Creek of 10.75m is almost 5 times the average width of Mary Creek at 2.53m. Also, the average depth of Chambers at 70.5cm is over 3.5 times deeper than Mary Creek. The pH at both locations is almost equivalent but the water velocity is much faster at Mary (.5172m/s) than at Chambers (.1089m/s) (table 1). These variables in physical characteristics concur with the low p-value when compared. These values lend to the idea that the functional feeding groups of the invertebrates would be expected to vary greatly. Although the number of families of invertebrates varied little at each location we did find some variability on the functional feeding groups. Both sites have a large proportion of collectors and grazers with chambers showing an unusual amount of predators (figure 2). We did not expect to see this type of variability given that the substrate type in each location was different. We also did not, h expect to see such a large amount of predators (58%) at Chambers Creek (figure 2). We expected to see a large amount of grazers and collectors that the RCC predicts at a mid order stream. This may be skewed somewhat because the predators are larger in scale compared to the other functional feeding group's and may be easier to see and thus easier to collect and tally. With these results we decided to look at results without the predators to see how the proportions of the functional feeding groups would change (fig 3). With the removal of predators from the analysis the streams were still found to be significantly different with a chi-square test; however the dominant FFG's other than predators remain shredders and collectors. The increase in grazers, however lends itself to the idea that Chambers Creek combines the characteristics of low and mid-order streams

We expected that the biotic and abiotic systems of each location would differ in accordance with the RCC. Mary Creek has a substrate made up mostly of CPOM and almost 100% canopy coverage making the area more likely to be a collector and shredder system. The faster current is very conducive to collectors and how they feed and the CPOM is the nutrient source for the shredder group of invertebrates. For Mary Creek what we found in our analysis is a carbon copy of what the definition of what the RCC is. Chambers Creek, however, has a substrate of FPOM and a silt/sand layer. The water is not very clear and the current moves slower in comparison to Mary Creek. These characteristics are indicative of a higher order stream yet Chambers is a small stream compared to higher order streams and contains a community composition that is more characteristic of low order streams.

Periphyton growth was supposed to be measured in both streams as one of our variables. However, when we went to collect data at Chambers Creek we found that one of clay plant pots used for the data collection was broken and out of the water while the other one was missing. The periphyton growth data was excluded from the analysis given these issues. It is worth noting, however, the growth on the rock substrate in Chambers Creek had heavy periphyton growth and the rocks at Mary Creek were moderately covered with periphyton, which supports the RCC (Vannote et al).

Possible errors and unforeseen problems in the data collection may have skewed certain results. One of the larger issues was the periphyton collection pots due to one being broken and out of the water. Also, predators are much larger than the other functional feeding groups so when collecting invertebrates they are easier to see and thus easier to collect. Therefore, this issue may have skewed some of the functional feeding group's results at Chambers Creek. Smaller functional feeding group's like collectors may have not been collected and therefore may not have been counted accurately in the study. For the collection of data we utilized 15 people who may have not known exactly what to look for in each collection sample. This could have resulted in a large proportion of functional feeding groups to also go unnoticed and mistakenly put back into the stream.

There have been many studies on invertebrates and stream ecology with respect to the RCC (Waters, T.F., 1965, Vannote et al, 1980, Merritt et al, 2008). From the data we collected it seems that the RCC provides a good base for forming hypotheses about stream systems, but it is by no means universal as was seen at Chambers Creek with the combination of characteristics of different orders.

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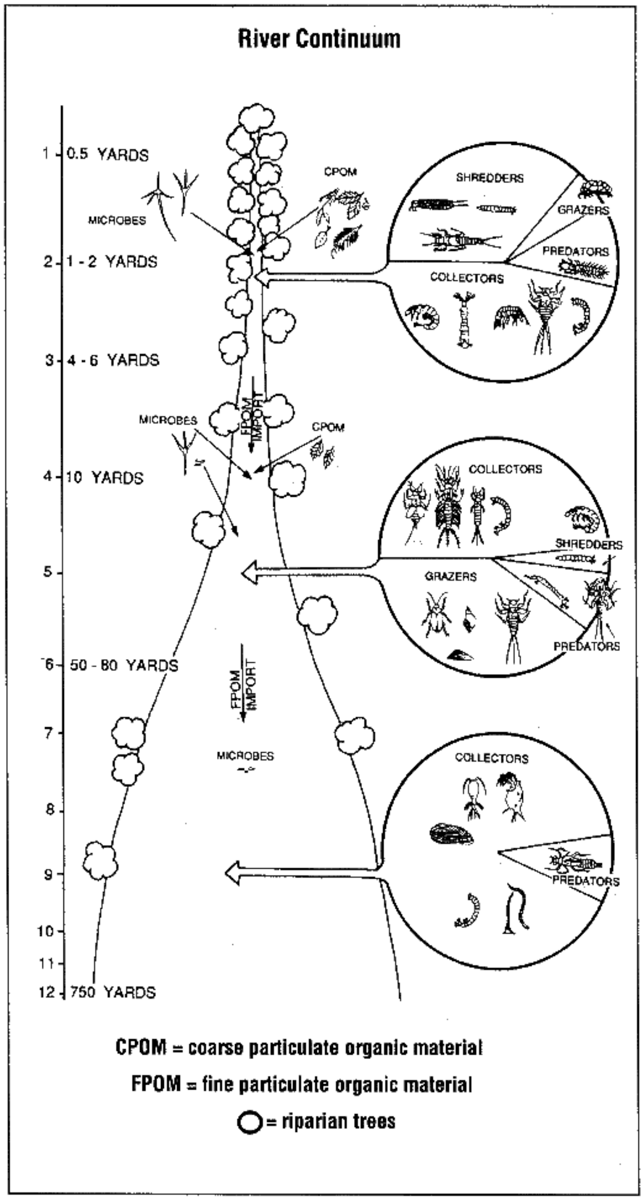
	Mary Creek	Chambers Creek
Width (m)	2.53	10.75
Depth (cm)	19.58	70.5
Current (m/s)	0.517	0.109
pH	7.74	7.89

Table 1: Average values of width, depth, and pH measurements taken at each site (current was measured only once at each site over 6 meters). All but pH were statistically significantly different between the two sites.

Sampling Site	Mary Creek	Chambers Creek
1	6	3
2	5	3
3	6	5
4	5	6
5	6	6
6	5	3
Average	5.5	4.3

Table 2: The numbers of insect orders found at each flag at each sampling site and the average values. The diversity at this level was not found to be significantly different (p-value 0.12)



www.d.umn.edu/~seaww/depth/rivers/02.html

Fig 1: River Continuum Concept from Vannote et al. 1980. Figure defines order of streams from 1-12 indicating differences in certain variables such as canopy coverage, functional feeding groups, width, and organic particle size.

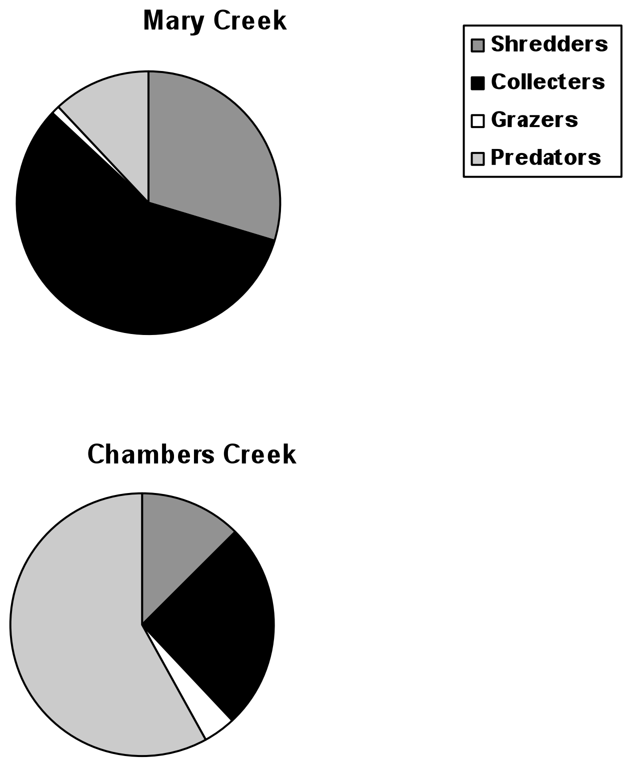


Fig. 2: The proportional composition on functional feeding group's sampled at each site showing the large difference found between the two areas. ($\chi 2$=192.64 with a critical value of 11.34 for α=0.01). The large proportion of predators at Chambers Creek is a point of interest.

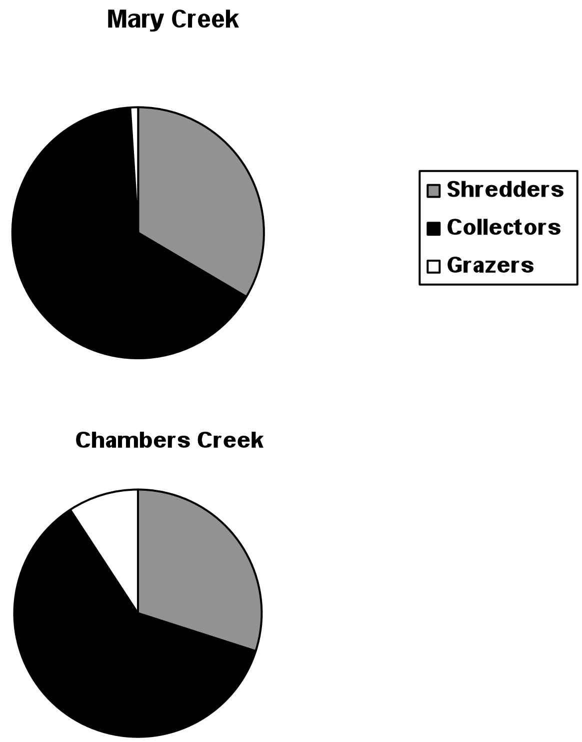


Fig. 3: A comparison between the proportions of FFG's between the two sites with predators removed. Both sites remain significantly different. ($\chi2=50.32$ with a critical value of 9.210 for $\alpha=0.01$)