# Spatial variation in headwater stream macroinvertebrate abundance and diversity

An Honors Thesis (HONRS 499)

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**Spatial Variation in Headwater Stream Macroinvertebrate Abundance and Diversity**

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**Abstract:**

We studied headwater streams in Delaware County, Indiana to quantify differences in macroinvertebrate assemblages and identify factors related to diversity of macroinvertebrates. We hypothesized that macroinvertebrate indices would differ with surrounding land-use as a result of physiochemical and hydrological properties. Weekly water samples and physiochemical measurements were collected from May-September 2008 in conjunction with macroinvertebrate samples collected using benthic surber samplers. Macroinvertebrates were brought back to the laboratory and identified to genus; macroinvertebrate indices were calculated for all sites. Percent Chironomidae/Oligochaeta, %Dominant Taxa, and Genera Richness all showed similar patterns among sites, while EPT differed little as a result of low numbers of Ephemeroptera, Plecoptera, and Trichoptera at all sites. Percent Chironomidae/ Oligochaeta abundance was correlated with pH. Low macroinvertebrate diversity is potentially due to agricultural and urban land-use in the surrounding watersheds. Low EPT values at all sites made it an ineffective index at detecting differences among sites and are indicative of highly degraded systems. Genera richness, percent dominant taxa, and percent Chironomidae/Oligochaeta were better indices at detecting changes in macroinvertebrate assemblages in these highly degraded watersheds.

## Introduction

Small streams receive water from the landscape and transport it to downstream ecosystems. The chemical and hydrological characteristics of a stream are a function of the surrounding geology, climate, and vegetation in the watershed (Carpenter 1992, Herlihy et al. 1998). Small streams serve as the initial site for the breakdown of allochthonous material such as leaf litter coming into the watershed from the surrounding land (Gessner & Chauvet 2002). As a result, anthropogenic activities may influence small stream structure and activity.

Because headwater streams are small and the organisms in them are largely dependent upon allochthonous materials, headwater streams are ideal study sites for assessing the influence of land-use on freshwater ecosystems. Delaware County, Indiana is dominated by urban and agricultural land-use and streams in the watershed have suffered hydrologic changes due to extensive channelization and the removal of vegetation from riparian zones. Activities such as row-crop agriculture and urban sprawl adversely affect aquatic habitats and the macroinvertebrate and fish communities that inhabit them (Wang et al. 1997). Water quality is adversely affected by nutrient and sediment loading that occurs from large agricultural areas such as row-crop agriculture (Walser & Bart 1999; Wang & Gatti 1997). Loss of buffer zones and channelization increase water temperature due to less shade and higher flow velocity (Meehan 1991, Cunjack 1996, Talmage et al. 2002).

An increase in light exposure caused by reduced riparian zones can cause an increase in periphyton and algal growth, further stimulating changes in small stream community structure. Further, a mixture of increased sun exposure in tandem with an increase of allochthonous material from altered land-use interact to produce an increase in primary productivity in streams causing changes in their trophic structures (Webster et al. 1983). Small streams are especially impacted by the removal of buffer zones since the effects of shading typically have a larger impact on headwater streams due to their smaller depth to width ratio (Rutherford 2004).

Stream macroinvertebrate assemblages are commonly used as bioindicators of stream quality due to their sensitivity to agricultural and urban pollutants but vary naturally due to changes in available habitat, nutrients, and chemical contaminants (Heatherly et al. 2007). Macroinvertebrates respond positively to increases in macrophyte abundance and substrate heterogeneity, indicating a trend in response to overall ecosystem heterogeneity (Vinson and Hawkins 1998). Because macroinvertebrate assemblages vary on regional and local scales (Heino et al. 2002), this makes them suitable systems for assessing spatial variation factors among streams. The abundance of macroinvertebrates can influence freshwater integrity at all trophic levels, thus the significance of understanding variability among stream macroinvertebrate assemblages is important in managing stream ecosystems.

The Upper White River Watershed of Delaware County, Indiana was among the most polluted in the United States in the early 1970's, but it has improved as water quality management efforts were increased in response to the serious pollution problem. However, the growth of Muncie's urban footprint, and the agricultural dominated land-use in the area surrounding the city, has continued to affect the water and habitat quality of the watershed. Thus, the need for continuous water monitoring is imperative in ascertaining exactly how and to what extent water quality is being affected by land-use in the area.

The objective of this study was to quantify differences in macroinvertebrate assemblages and to assess what might be driving those differences in the streams of the Upper Whiter River Watershed of Delaware County, Indiana. We hypothesized that macroinvertebrate indices would differ with surrounding land-use as a result of differing physiochemical compositions among streams.

## Methods

### ***Study Sites***

Four headwater streams, Jake's Creek, a tributary of No Name Creek, Muncie Creek, and York Prairie Creek, were selected in the Upper White River Watershed in Delaware County, Indiana for establishment of long-term study sites (Figure 1.) Sites were chosen to be representative of the diversity of small streams within Delaware County through initial data collected via water samples and site reconnaissance.

Jake's Creek flows through a residential area of Muncie, IN before entering an artificial pond. It then exits the pond via a rock-filled dam, flowing into a wooded area. The study site on Jake's creek is located just below the rock-filled dam on Ball State University's Cooper Field Station property. The site is located in full sun at the transition between a residential and wooded area. The riparian zone is dominated by tall grass transitioning into large trees and shrubs. The substrate is dominated by silt and sand.

The tributary of No Name Creek is located in a rural residential area just downstream of a livestock farm. It is adjacent to a light-traffic road where it passes under the road via a large culvert before merging with No Name Creek. The tributary is heavily shaded with the riparian zone dominated by large trees and shrubs. The substrate is primarily cobble and sand.

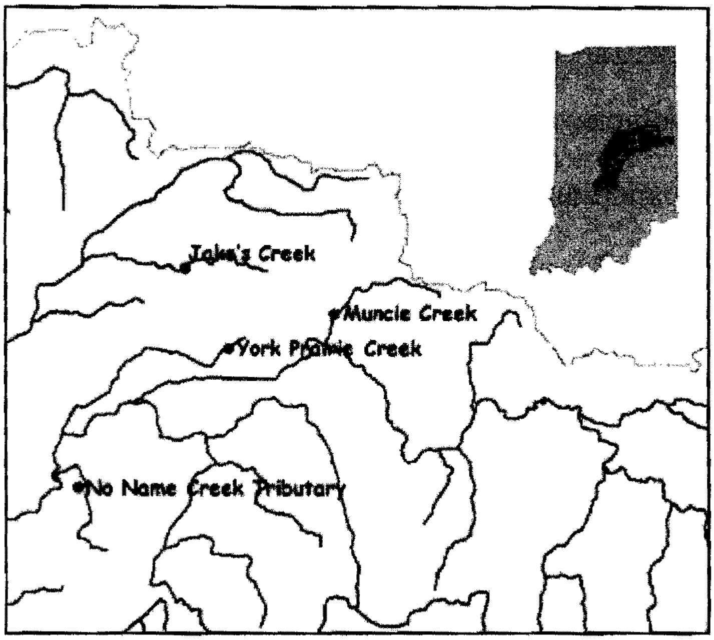

Figure 1. Locations of sampling sites in the Upper White River Watershed of central Indiana.

Muncie Creek flows through large row-crop fields before flowing through the city of Muncie and emptying into the White River. The Muncie Creek site is located in a commercial area near a heavy-traffic road and directly adjacent to a car repair shop with a light-traffic road on the opposite side. There are several visible point-source inputs into the stream, and the riparian zone is dominated by short, city maintained grass. The stream is channelized with concrete in some places, and the area receives full sun. The substrate is dominated by sand and silt.

Lastly, York Prairie Creek flows through the Ball State University campus before entering into a residential area. The site is located on the outskirts of the campus as the stream leaves a pond. The riparian zone is dominated by small grasses, shrubs, and trees and receives partial sun throughout the day. The substrate is dominated by cobble and sand.

***Physiochemical and Macroinvertebrate Measurements***

Bi-weekly water samples and physiochemical measurements were collected from the thalweg of each stream from June-September 2008 (Figure 2). Water samples were filtered using 25 mm GF/F glass filters, frozen, and stored until analyzed. Water samples were analyzed for nitrate, phosphate, sulfate, fluoride, and chloride using a Dionex ion chromatograph. Physiochemical parameters (pH, turbidity, dissolved oxygen, conductivity, temperature) were measured using a Hydrolab minisonde equipped with an LDO sensor.

Macroinvertebrates were sampled on June 17, July 14 and September 6, 2008 (Figure 2). A twenty meter reach at each site was randomly selected for three timed (3 minutes) surber samples. Surber samples were collected ten meters apart at the 0 m, 10 m, and 20 m increment within the reach. The 20 m reaches were divided into two 10 m reaches and D-nets were used to sample the riparian zone of each by vigorously scraping the area along the edges of the stream for 3 minutes. Macroinvertebrate samples were taken back to the laboratory where macroinvertebrates were picked and identified to genus using a key by Merritt and Cummins (1996) followed by the calculation of the following macroinvertebrate indices:

1) EPT = sum of Ephemeroptera, Plecoptera, and Trichoptera taxa

2) % Chironomidae:Oligochaeta =sum of the number of Chiromidae and Oligochaeta divided by total number of families in a sample

3) Genera Richness = total number of genera present at a site

4) % Dominant Taxa = Number of individuals from the most abundant taxa divided by total number of individuals * 100

Statistical analyses were conducted using statistical analysis system (SAS). One-way analysis of variance (ANOVA) test was used to compare mean macroinvertebrate indices among sites followed by Tukeys and pairwise comparison Pearson correlations.

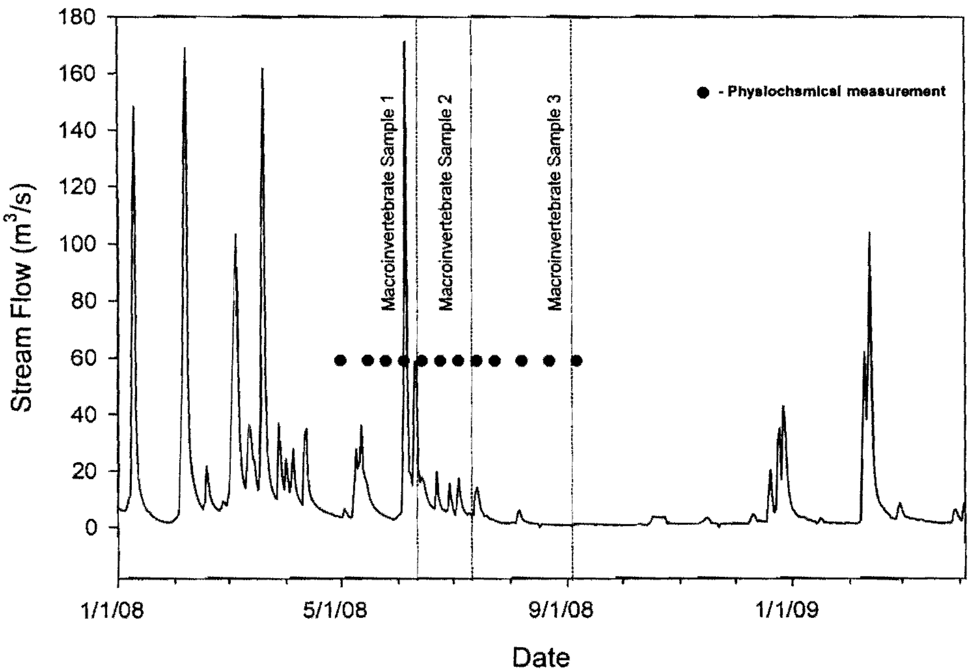


Figure 2. Hydrograph of the sampling period in the Upper White River Watershed.

## Results

Nitrate concentrations (mg/l) varied both among sites and within sites temporally (Figure 3) with Muncie Creek and No Name Creek Tributary having much higher nitrate levels. Phosphate concentrations (mg/l) also differed among sites and within sites temporally; temporal changes in phosphate concentrations (mg/l) were more pronounced than in nitrate concentrations (mg/l), rising during the late summer and falling in late winter (Figure 3). Among sites, pH levels declined temporally with higher pH levels in the spring declining steadily through winter (Figure 4).

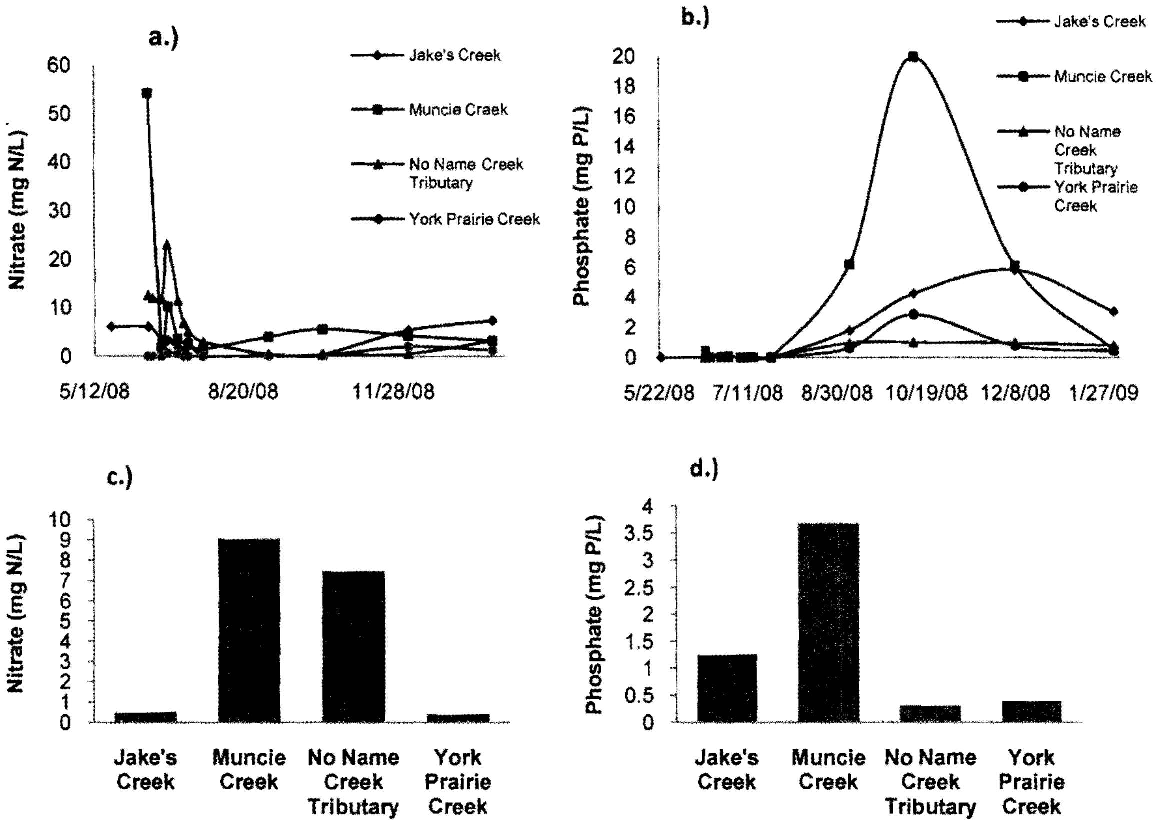


Figure 3.Chemical concentrations measured in stream water. a.) Spatial and temporal variation in nitrate concentrations, b.) spatial and temporal variation in phosphate concentrations, c.) mean nitrate concentraton per site, and d.) mean phosphate concentration per site.

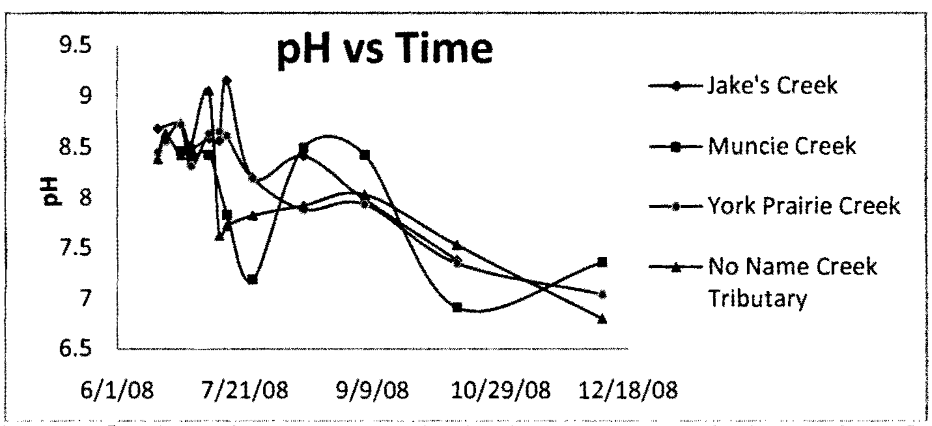


Figure 4. Spatial and temporal variation in pH for streams in the Upper White River Watershed.

Chironomidae and Oligochaeta constituted the majority of taxa present at most sites, with %Chironomidae/Oligochaeta being over 50% for all but one sample. Genera richness differed among sites with No Name Creek Tributary having more genera present than in other sites in the three samplings. Percent Chironomidae/Oligochaeta, %Dominant Taxa were higher is sites with lower genera or famility richness. The site with the lowest mean genera richness was York Prairie Creek, with No Name Creek Tributary having the highest richness. Percent Dominant Taxa was often high for sites with high %Chironomidae/Oligochaeta numbers since one of those taxa generally was the dominant taxa. EPT differed little as a result of low numbers of Ephemeroptera, Plecoptera, and Trichoptera among site (Table 1). Data suggest that percent Chironomidae/Oligochaeta differed with pH concentrations among sites, but more data is needed (Figure 5).

Table 1. Summary of macroinvertebrate indices at each site.

| Site | Date | EPT | %Chironomidae/Oligochaeta | %Dominant Taxa | Genera Richness |
|---|---|---|---|---|---|
| Cooper | 6/17/2008 | 0 | 86.2 | 81.7 | 7* |
| Cooper | 7/14/2008 | 0 | 94.3 | 55.7 | 7 |
| Cooper | 9/6/2008 | 0 | 65.3 | 37.3 | 9 |
| Muncie Creek | 6/17/2008 | 1 | 47.3 | 41.9 | 10* |
| Muncie Creek | 7/14/2008 | 1 | 67.4 | 43.3 | 10 |
| Muncie Creek | 9/6/2008 | 1 | 75 | 75 | 15 |
| No Name Creek | 7/14/2008 | 3 | 54.6 | 49.2 | 26 |
| No Name Creek | 9/6/2008 | 1 | 35.9 | 30.8 | 24 |
| No Name Creek | 6/17/2008 | 1 | 85.3 | 81.3 | 9* |
| York Prairie Creek | 6/17/2008 | 0 | 89.1 | 78.2 | 5* |
| York Prairie Creek | 7/14/2008 | 0 | 82.9 | 40.1 | 8 |
| York Prairie Creek | 9/6/2008 | 0 | 100 | 73.1 | 2 |

Values indicated with * indicate samples that were identified only to family

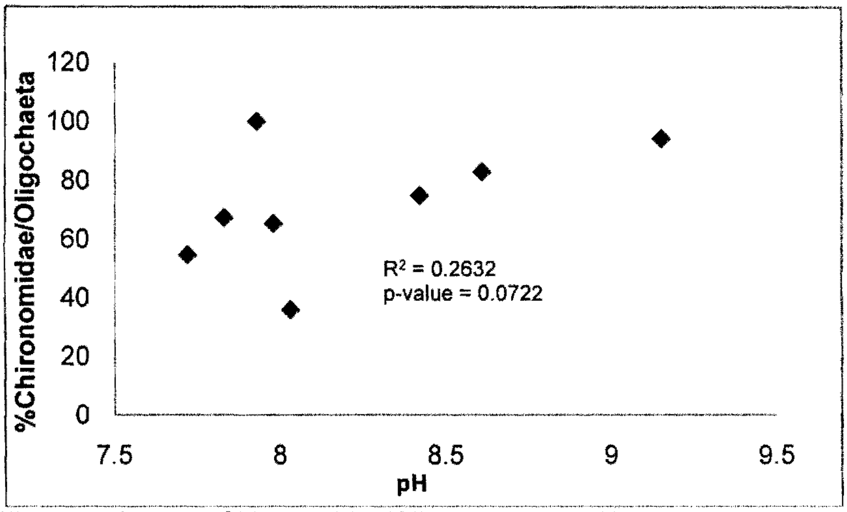

Figure 5. Percent Chironomidae/Oligochaeta vs. pH levels among sites in the Upper Whiter River Watershed

**Discussion:**

Percent Chironomidae/Oligochaeta was high for all of the sites with these two taxa constituting the majority of taxa present. No Name Creek Tributary had the lowest %Chironomidae/Oligochaeta, which correlates with it also having the lowest average pH among samplings. As steams receive increased amounts of organic pollution, oligochaetes and chironomids become more abundant (Hilsenhoff 1987, Wetzel 2001). Percent Chironomidae has also been shown to increase with increased sediment loading (Kreutzweiser et al. 2004). EPT values were low for all sites given the few specimens collected from the Ephemeroptera, Plecoptera, and Trichoptera taxa. Ephemeroptera prefer environments with high oxygen and low to moderate pollution, while trichoptera and plecoptera live in high oxygen environments ranging from low to high pollution (Merritt & Cummins 1996, Wetzel 2001). With the sensitivity of Ephemeroptera, Plecoptera, and Trichoptera to high levels of organic pollution, and due to the relatively high concentrations of nitrate, phosphate, and sulfate, EPT's were likely low due to degradation of streams. Because of the overall condition, EPT's were not as sensitive to changes in physiochemical parameters as previous studies have noted (Wallace et al. 1996).

Chironomids have been suggested as bioindicators of acidified streams (Orendt 1999). Our results suggest that percent Chironomidae/Oligochaeta increased with basic conditions suggesting that either 1) these taxa are increasing in abundance at higher pH or 2) these taxa are more tolerant to a wider range of alkaline conditions. Past research indicates that the latter is true since highly diverse chironomid assemblages were shown to be replaced by fewer, more tolerant species under increasing acidic conditions (Armitage et al. 1995).

Some physiochemical parameters, such as nitrates and phosphates, were not shown to be driving macroinvertebrate assemblages in Delaware County despite correlations found among these variables in past research (Haefner and Wallace 1981, Kreuger and Walters 1983, Corkrum 1996). However, nitrate and phosphate concentrations in streams were high, which suggests that these two nutrients are no longer limiting resources for the macroinvertebrate assemblages.

Management efforts of headwaters streams using macroinvertebrate assemblage indices should take into consideration the degree of which the streams are degraded. By first making an estimate of degradation based upon surrounding land-use, managers can choose macroinvertebrate indices which are more sensitive to changes in stream physiochemical parameters potentially allowing for more accurate assessments of overall degradation.

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