---

# Rice Creek: Differences in chemical properties and aquatic macroinvertebrate populations between forested and agricultural sites

Sarah Bond

2017

# Rice Creek: Differences in chemical properties and aquatic macroinvertebrate populations between forested and agricultural sites

Sarah Bond
Field Ecology 371
December 2017

## Abstract

Using biota as important indicators of environmental quality improves upon standard chemical monitoring systems. Invertebrate communities are often used for aquatic bioassessment investigations. Rice Creek in Northfield, MN, is a cold trout stream surrounded by agricultural land and patches of forestry. Agricultural activities are primary contributors to the degradation of streams and lakes in the United States. This study tested the differences in water quality and macroinvertebrate populations between agricultural and forested areas and answers whether macroinvertebrate populations are adequate indicators of water quality. The goal of this study is to understand the relationship between water qualities and macroinvertebrate populations as well as provide evidence for conserving forested areas around stream communities. As one of the few streams in the state with native brook trout, it is important to understand the stream's general health as well as the effect of human actions at the landscape scale. Four study sites were sampled three times for chemical properties. Macroinvertebrates were collected and identified. The data reveals no significant differences between agricultural and forested sites over each sampling period but that the water quality of Rice Creek is not ideal for trout and many other organisms. It provides evidence for increased compliance with Minnesota buffer laws and to decrease disturbance of the stream to preserve healthy aquatic communities.

## Introduction

Rice Creek is a cold-water trout stream located in Northfield, MN. It is the only trout stream in Rice County and one of the few in the state with native brook trout. This creek drains an agricultural area of about 7 square miles, starting near I-35 and ending in the Cannon River. Rice Creek provides a wildlife corridor for organisms through agricultural and forested areas and the watershed includes parts of Northfield, Dundas, and unincorporated areas of Bridgewater

Township. The entire watershed was once part of the Big Woods and covered with maple, basswood, elm, and oak forests interspersed with wetlands. The vegetation is now primarily agricultural crops with smaller fragmented forests. Because of buffer laws, grassed buffers through the agricultural land protect parts of the creek. The superficial geology of the creek is made up of thin glacial deposits, underlain by sedimentary rock with gravel deposits near the lower end of the creek (Committee Report, 1999).

A stream that receives contaminants or has been altered from natural conditions tends to have a less diverse community of benthic invertebrates. Large percentage contributions by a few taxa indicate less even invertebrate communities, which are indicative of less healthy streams. The abundance of a healthy invertebrate community usually is distributed somewhat evenly among taxa (McPherson, 2005). Benthic macroinvertebrates are bottom-dwelling aquatic organisms, such as insect larvae, mollusks, and worms, that fill many niches in aquatic ecosystems. They recycle organic matter, consume smaller organisms, and are important components in the diet of fishes. Macroinvertebrates commonly are used to assess the health of aquatic communities because they are easy to collect and identify and are usually abundant. Benthic invertebrates typically integrate the effects of water quality over periods of about a year and can be more sensitive indicators of water quality than chemical measures (McPherson, 2005). For this reason, macroinvertebrate populations were included as bioindicators of stream health in this study.

The chemistry of freshwater streams is formed by many factors. Qualities such as dissolved oxygen depend on biotic responses to nutrient levels and temperature. In Minnesota, the major concern for stream health is large nutrient loads leached from the vast amount of cropland (Allan, 2004). Increased levels of nutrients like nitrates and phosphates are indicators of agricultural runoff and can greatly affect biotic and abiotic components of stream health (Whiles, 2000).

This study will look at water quality differences caused by the surrounding land composition of the creek and the resulting effects on the aquatic macroinvertebrate community in order to determine the health of the stream and future ability to support the trout population. Understanding the impact of land use on stream ecology and how macroinvertebrates respond to differences in water chemistry is vital for community conservation. As one of the only streams in the state with native trout, it is important to check up on the water quality to determine the direction of the community. The macroinvertebrate community is largely influenced by the surrounding land use, which can help determine how the health of the stream is affected by different actions. Human actions at the landscape scale are a principal threat to the ecological integrity of river ecosystems by impacting habitat and water quality so by sampling in both areas surrounded by forestry and agricultural fields, the impact of land use on Rice Creek can be observed.

## Methods

This study took place at four sites on Rice Creek, two surrounded by agricultural fields and two surrounded by forest. The sites were sampled three times between the end of October and early November of 2017. Observational data was recorded at each site including depth of water, amounts of leaf litter and organic matter, and any phenological changes from the previous sampling time. Chemical data (DO, pH, conductivity, temperature) were recorded using probes, and water samples were collected to determine nitrate concentrations in the lab. Aquatic macroinvertebrates were collected with two thirty-second kick net attempts. All attempts were of equal effort and time at each site and sampling time. All organisms were taken back to the lab and identified to species when possible using a dissecting microscope. Shannon-Simpson diversity indices were calculated using a Field Ecology excel spreadsheet, and t-tests were performed to determine pairwise comparisons of sites. The statistical program R (version 3.4.1) was used to perform contingency analyses on the most common species at each site to determine the change in proportions of species over time. ANOVA tests were competed by site and time with all response variables (DO, pH, conductivity, temperature, and nitrate concentration) to determine significant differences in values. Significance was determined using p-values for each test.

**Results**

Of the 528 macroinvertebrates collected, 159 were at site 1, 304 at site 2, 28 at site 3, and 37 at site 4 (Table 1). Site 1 had significantly different proportions of the three most common species at each time (X-squared= 58.53, $p < 0.01$) (Table 2, Graph 1). Site 2 also had significantly different proportions of the three most common species at each time (X-squared = 13.93, $p = 0.0075$) (Table 3, Graph 1). Sites 3 and 4 did not have significantly different proportions of species (Tables 4 and 5, Graph 1). The Simpson diversity equation revealed that sites 3 (0.81) and 4 (0.73) had the highest diversity of macroinvertebrates (Table 6). Sites 1(0.59) and 2 (0.30) had lower diversity. T-tests using Simpson's values showed significant difference in diversity ($p<0.05$) between sites 1-2, 1-3, 1-4, 2-3, and 2-4, but not between sites 3-4 (Table 7). There were no statistically significant differences between DO, pH, conductivity, temperature, and nitrate concentration by site or time but graphical representation of site averages can show some trends for the stream (Figures 2, 3, 4). The lack of statistical significance is most likely due to the small sampling sizes.

**Discussion**

The changes in species proportions over time between sites 1 and 2 shows that an ecological property changed between sampling that decreased the populations. Not only did the overall number of macroinvertebrates decrease over time, the more sensitive organisms disappeared (mayfly) while the hardier organisms remained (scud, pouch snails). This result was somewhat surprising because sites 1 and 2 are forested areas and presumably undisturbed. It was expected that the larger changes would occur at the agricultural sites where disturbance is more frequent due to harvesting and field treatments. Harvesting on most croplands near Rice Creek occurred between the first and second sampling. This is likely the cause of the shift in species proportions. The fact that the highest diversity also occurred at the agricultural sites was surprising as well. It was hypothesized that the larger diversity would occur at forested sites with the assumption that the water quality and overall habitat quality would be better. Although there were more species at the forested sites (11 and 9, respectively), there was a huge abundance of just one or two species, which decreases diversity. This is also indicative of an unhealthy stream (McPherson, 2005). These results show that the fact that the water was surrounded by forest had little affect on stream quality. It was noted during the second sampling that the smell of manure was present at the forested sites, indicating that fertilizer had infiltrated the area even though the nearest field was about 800 meters away. This is most likely due to a heavy rain event that occurred just after the harvest, causing an increase in runoff and nutrient leaching. Further, increased levels of mossy, photosynthetic material and algae increased between the first and second sampling at all sites. This shows that the affect of the agricultural land went beyond the sites that were in direct proximity to the crops.

Trends in chemical quality measures were present at many sites and times. The average nitrate levels were higher at the agricultural sites than at forested sites because of the direct proximity to the fields. At both agricultural sites, buffering did not sufficiently comply with the Minnesota Buffer Law, which states that rivers, streams, and ditches must be surrounded by 50 feet of perennial buffering to filter out phosphorus nitrogen, and sediment (Minnesota Department of Natural Resources 2017). Without the proper buffering, excess nutrients and sediment are passing beyond agricultural areas and to forest fragments downstream. This is reflected in dissolved oxygen fluctuations at all sites. Increased oxygen levels increase the production efficiency of primary producers, which increases levels of oxygen for a short time. As the primary producers begin to die, bacteria on the bottom of the stream will begin to decompose the plant bodies. This causes a decrease in dissolved oxygen than can be dramatic enough as to kill off many oxygen sensitive species, including fish. Trout are most limited by oxygen concentration, which makes it a very important chemical to study in Rice Creek. Eutrophication did not occur during this study although plant matter increased significantly. Oxygen levels at each site increased between the first and second sampling and decreased at the third sampling.

The overall health of the stream was determined by comparing average chemical values to the ideal values for brook trout and by examining the macroinvertebrate populations. As the most common limiting factor for trout, the ideal dissolved oxygen level is 11 mg/L. Trout cannot survive less than 5 mg/L. The lowest DO value was 7.77 mg/L and the average between all sites was 9.88 mg/L. The optimal pH is 6.5-8 and the tolerance level is 4-9.5. There were two occurrences of pH above 9.5 and the average between all sites was 8.75. Trout can survive in 0-24 degrees Celsius and the range between all sites was 6.5-12.1 degrees Celsius. Conductivity in a healthy stream should be between 150-500 uS. The range at all sampling sites was 504-578 uS. Trout are tolerant of nitrate concentrations of 5-40ppm and the Rice Creek range was 1.3-17.8ppm. The chemical values indicate a stream that can support trout but is not ideal. Diversity of macroinvertebrate populations was low across all study sites and especially low at forested sites. The large numbers of macroinvertebrates at the forested sites primarily consisted of a few hardy species (Amphipoda). This is indicative of an unhealthy stream because the water quality is not sufficient to support a diverse population of macroinvertebrates.

The majority of trout and other fish species were observed at site 2. While this site did not have the most ideal temperature or oxygen levels for trout, the chemical levels remained consistent throughout the sampling period. This may be why that location always had a large population of fish present. The benefits of a consistent environment highlight the fact that agricultural activities need to cause fewer disturbances to aquatic systems in order to preserve healthy communities. Stream health deteriorates when there are deviations from the normal ecology.

Although there were not significant differences between forested and agricultural sites for any chemical property, this result still gives relevant information about the health of Rice Creek. Areas not directly surrounded by agricultural land were still affected by changes such as applying fertilizer and harvesting. These affects were exacerbated by heavy rain events because nutrients and sediment can travel long distances. Land use along the entire catchment area can govern water quality and this was shown through the overall poor health of the stream (Allen 2006). Future studies should increase sampling size to find significant results to report so that policy changes can be made to increase the health of Rice Creek. While buffer laws are in place, compliance has not been achieved on many farms in Northfield and Dundas. Improving manure storage and creating grassed waterways could also mitigate agricultural impacts. Rice Creek is not currently a healthy trout stream, but there is potential to improve the water quality and secure a healthy future for the entire stream community.

## Literature Cilted

Allan, David J. 2004. LANDSCAPES AND RIVERSCAPES: The Influence of Land Use on Stream Ecosystems. *Annual Review of Ecology, Evolution, and Systematics.*

McPherson, Ann et al. 2005. Assessment of water quality, benthic invertebrates, and periphyton in the Threemile Creek basin, Mobile, Alabama, 1999-2003. *Aquatic Sciences and Fisheries Abstracts.*

Minnesota Department of Natural Resources. 2017. “Minnesota Buffering Protection Maps.” Accessed at dnr.state.mn.us

Whiles, Matt R. et al. 2000. Stream Invertebrate Communities, Water Quality, and Land-Use Patterns in an Agricultural Drainage Basin of Northeastern Nebraska, USA. *AGRICOLA.*

Yates, Adam G. 2007. Effectiveness of best management practices in improving stream ecosystem quality. *AGRICOLA*.

Spring Brook Committee Report, 1999. As recommended by the Legislative Commission on Minnesota Resources.

J. David Allan. 2004. LANDSCAPES AND RIVERSCAPES: The Influence of Land Use on Stream Ecosystems. *Annual Review of Ecology, Evolution, and Systematics.*

**Tables and Figures**

Table 1: distribution of total sampled aquatic macroinvertebrates by site.

| **Common Name** | **Site 1** | **Site 2** | **Site 3** | **Site 4** |
|---|---|---|---|---|
| backswimmer | 1 | 0 | 0 | 0 |
| caddisfly larva | 2 | 0 | 0 | 0 |
| caterpillar | 0 | 0 | 0 | 2 |
| caterpillar | 0 | 1 | 0 | 0 |
| cranefly larva | 1 | 0 | 2 | 1 |
| damselfly adult | 0 | 0 | 0 | 1 |
| damselfly larva | 51 | 0 | 1 | 3 |
| dragonfly larva | 0 | 1 | 0 | 0 |
| horsehair worm | 0 | 0 | 4 | 0 |
| hydrobiid snail | 0 | 0 | 0 | 3 |
| long legged fly larva | 0 | 0 | 1 | 0 |
| mayfly adult | 0 | 0 | 1 | 0 |
| mayfly larva | 6 | 0 | 0 | 0 |
| midge adult | 0 | 1 | 0 | 0 |
| midge larva | 1 | 2 | 3 | 0 |
| orb snail | 2 | 1 | 0 | 0 |
| pouch snail | 3 | 45 | 6 | 9 |
| scud | 89 | 251 | 10 | 17 |
| slug | 0 | 1 | 0 | 0 |
| water penny larva | 0 | 1 | 0 | 0 |
| water scavenger beetle | 2 | 0 | 0 | 1 |
| whirligig beetle | 1 | 0 | 0 | 0 |
| **Total** | **159** | **304** | **28** | **37** |

Table 2: Site 1 species proportions by row and counts using top 3 most common species

*X-squared = 58.53* *p = 5.92e-12*

| **Species** | **Time 1** | **Time 2** | **Time 3** |
|---|---|---|---|
| **Damselfly larva** | 0.961 (49) | 0.039 (2) | 0 (0) |
| **Scud** | 0.359 (32) | 0.168 (15) | 0.472 (42) |
| **Mayfly larva** | 0.272 (3) | 0.455 (5) | 0.273 (3) |

| Table 3: Site 2 species proportions by row and counts using top 3 most common species | | | | | |
|---|---|---|---|---|---|
| *X-squared = 13.93* | *p = 0.0075* | | | | |
| | | | | | |
| **Species** | **Time 1** | **Time 2** | **Time 3** | | |
| **Pouch snail** | 0.444 (20) | 0.533 (24) | 0.022 (1) | | |
| **Scud** | 0.514 (129) | 0.311 (78) | 0.175 (44) | | |
| **Midge larva** | 0.50 (1) | 0.00 (0) | 0.50 (1) | | |

| Table 4: Site 3 pecies proportions by row and counts using top 3 most common species | | | | | |
|---|---|---|---|---|---|
| *No X-squared or p-value possible because most common species did not appear in time 1.* | | | | | |
| | | | | | |
| **Species** | **Time 1** | **Time 2** | **Time 3** | | |
| **Pouch snail** | 0.00 (0) | 0.00 (0) | 1.00 (6) | | |
| **Scud** | 0.00 (0) | 0.30 (3) | 0.70 (7) | | |
| **Midge larva** | 0.00 (0) | 0.333 (1) | 0.667 (2) | | |

| Table 5: Site 4 species proportions by row and counts using top 3 most common species | | | | | |
|---|---|---|---|---|---|
| *X-squared = 5.66* | *p = 0.227* | | | | |
| | | | | | |
| **Species** | **Time 1** | **Time 2** | **Time 3** | | |
| **Pouch snail** | 0.333 (3) | 0.333 (3) | 0.333 (3) | | |
| **Scud** | 0.706 (12) | 0.118 (2) | 0.176 (3) | | |
| **Damselfly adult** | 1.00 (3) | 0.00 (0) | 0.00 (0) | | |

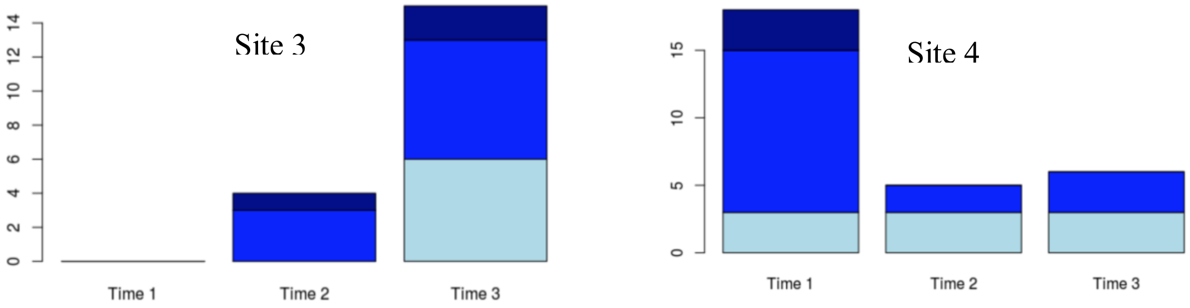


Figure 1: Graphical representation of contingency analyses. Proportions of three most common species over sampling times 1, 2, and 3.

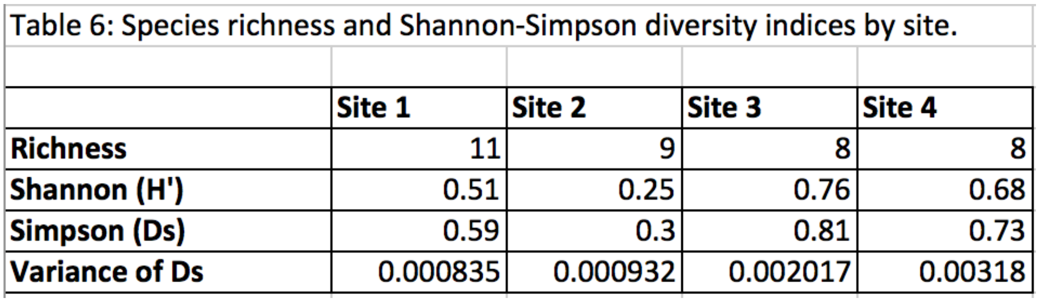


Table 6: Species richness and Shannon-Simpson diversity indices by site.

| | Site 1 | Site 2 | Site 3 | Site 4 |
|---|---|---|---|---|
| **Richness** | 11 | 9 | 8 | 8 |
| **Shannon (H')** | 0.51 | 0.25 | 0.76 | 0.68 |
| **Simpson (Ds)** | 0.59 | 0.3 | 0.81 | 0.73 |
| **Variance of Ds** | 0.000835 | 0.000932 | 0.002017 | 0.00318 |

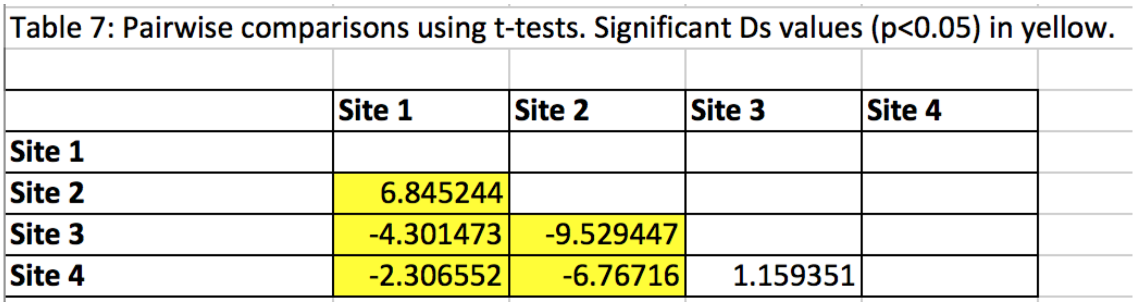
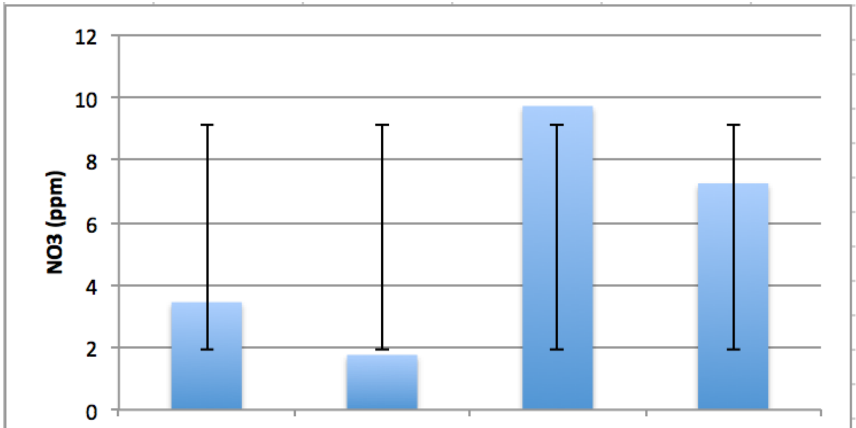


Table 7: Pairwise comparisons using t-tests. Significant Ds values (p<0.05) in yellow.

| | Site 1 | Site 2 | Site 3 | Site 4 |
|---|---|---|---|---|
| **Site 1** | | | | |
| **Site 2** | 6.845244 | | | |
| **Site 3** | -4.301473 | -9.529447 | | |
| **Site 4** | -2.306552 | -6.76716 | 1.159351 | |



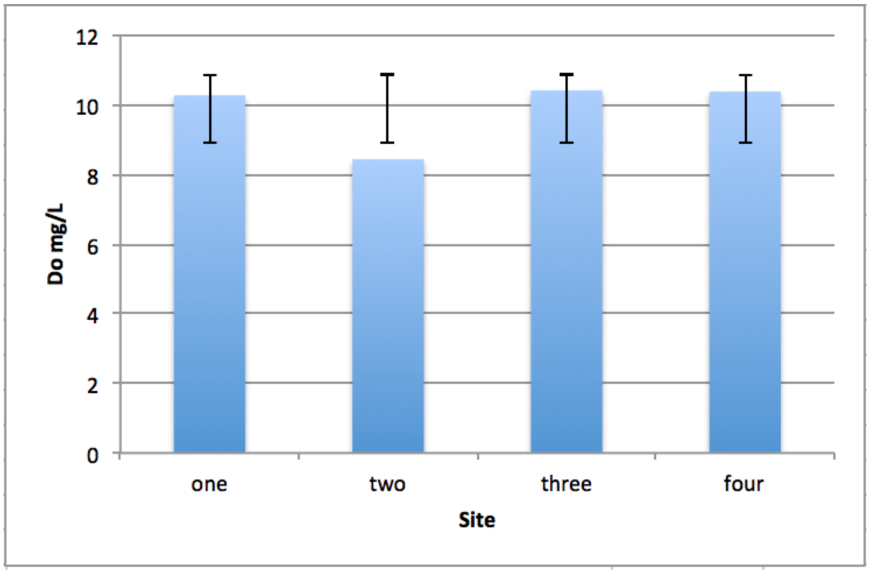


Figure 3: Average dissolved oxygen by site.

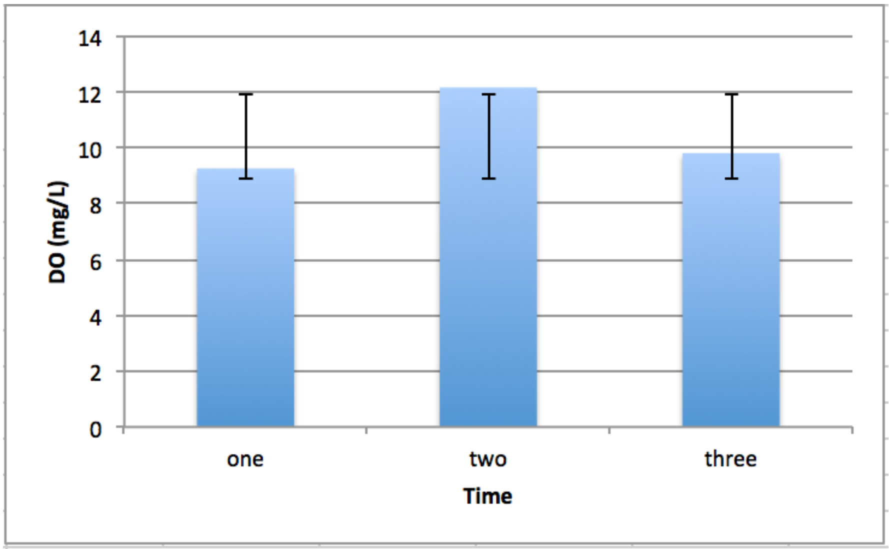


Figure 4: Dissolved oxygen concentration at site 3 by sampling time one, two, and three.