The Effects of Urbanization on Leaf Breakdown Rates in a Rock Island Watershed

Jillian M. Jespersen
Augustana College, Rock Island Illinois

Laura Becker
Augustana College - Rock Island

Kortney Hix
Augustana College - Rock Island

C. Kevin Geedey
Augustana College - Rock Island

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Augustana College Biology Department

Introduction

Urbanization is a rapidly growing form of land change that is almost inevitable for growing populations. Today, more than 75% of the United States population occupies urban areas (Paul et al. 2001). The ecological footprint that follows urbanization can be extremely detrimental for many aspects of the ecosystem, including streams that drain newly urbanized areas (Paul et al. 2001, Martins et al. 2015). The conversion of land use from rural and forested to urban can negatively affect stream ecosystems by altering trophic resources, hydrology, geomorphology, biodiversity, and water chemistry (Chadwick et al. 2006, Martins et al. 2015). Along with urbanization, increases in impervious surfaces tend to heavily influence the ecology and health of urban streams (Chadwick et al. 2006, Martins et al. 2015). Many studies have illustrated that an increase in imperious surfaces, which is a side effect of urbanization, decreases stream biotic health by reducing biodiversity, increasing runoff, simplifying channel morphology, increasing pollutants, and decreasing invertebrate diversity; this phenomena is known as the urban stream syndrome (Chadwick et al. 2006, Martins et al. 2015). Aspects of stream health can be derived from observation of stream functions, one key functions being the decomposition of leaves (Benfield 2006, Chadwick et al. 2006, Martins et al. 2015, Young et al. 2008).

There are two main energy sources for streams: instream photosynthesis and imported organic matter from overhead forest cover or streamside vegetation (Benfield 2006). Forested streams rely heavily upon imported organic matter through the decomposition of CPOM to FPOM (leaves to small particulates) (Allan et al. 2007). Larger streams and rivers not surrounded by forest therefore rely on the transformation of CPOM to FPOM in forested streams as their main energy source (Allan et al. 2007). Without the ecosystem service of leaf decomposition provided by small streams, large streams can become unable to sustain their inhabitants (collectors) while being burdened with excess unusable CPOM (Allan et al. 2007). Because imported organic matter is such a pivotal part of stream function, it is necessary to observe leaf litter decomposition in order to assess a stream's function and health. The decomposition of leaf litter is heavily influenced by the presence of invertebrates, bacteria, temperature, nutrients, and the type of leaf present (Dunck et al. 2015, Garcia et al. 2012, Graca 2001, Martins et al 2015, Tarrant et al. 2009) Invertebrates are observed to play one of the main roles in the decomposition of leaves; they actively break down leaves into smaller pieces by exposing more surface area to microbial colonization, therefore increasing the decomposition rate (Allan et al, 2007, Graca 2001, Tarrant et al 2009). In studies where invertebrates have been eliminated by insecticides, the decomposition rates of leaves significantly decreased, suggesting that invertebrates play the main role in decomposition in the majority of streams (Allan et al. 2007). A healthy stream, therefore, can be characterized as one with a rich diversity of invertebrates that actively break down leaf litter (Chadwick et al. 2006). Likewise, the more nutrients (organic pollutants) that are found in streams, there was found to be a more diverse presence of invertebrates (Dunck et al. 2015, Silva-Junior et al. 2014, Wymore et al. 2015). Along with urbanization comes an increase in pollutants (chlorides) and nutrients (N and P) due to impervious surfaces and agricultural runoff (Chadwick et al. 2006, Martins et al. 2015). This increase in pollutants and nutrients can affect stream ecosystem in many ways. More sensitive and essential invertebrate species can be eliminated while more tolerant species thrive due to an intermediate increase in nutrients and pollutants (Pascoal et al. 2005). However, too large of an increase can eliminate the majority of species which can negatively affect leaf decomposition rates (Pascoal et al. 2005). In either case, increasing nutrients and pollutants due to urbanization can affect the invertebrate diversity and thus the rate of leaf breakdown in urban streams.

According to the Upper Mississippi River Center, the area of Rock Island from 18th avenue to Blackhawk Road is drained by a single catchment system that empties into the Rock River. It has been observed through preliminary research that many of the individual sites within the watershed are impaired (Upper Mississippi Studies Center, unpublished data). These assessments are based on, total dissolved and suspended solids (chlorides), ammonia,, nitrate, and phosphorus levels observed at points in the catchment. A small number of sites found in heavily forested areas are of fair quality (Blackhawk Forest

Preserve mainly) , but the majority of the urbanized streams are poor to very poor. The Rock Island watershed appears to be experiencing symptoms of the urban stream syndrome discussed above. The Upper Mississippi River Center is interested in the effects urbanization has inflicted upon the catchment system, the biodiversity of its inhabitants, as well as the overall health of the watershed. By locating and understanding intact ecosystem services within the Rock Island watershed the prospect of restoring parts of the catchment may be a possibility. One very simple and cost-effective way to assess intact ecosystem services is to observe rates of leaf breakdown (Benfield 2006, Chadwick et al. 2006, Young et al. 2008). As mentioned above, leaf breakdown is rather dependent on the diversity and biomass of invertebrates (Chadwick et al. 2006). Therefore, areas observed to have normal levels of leaf breakdown (in comparison to a reference stream) could possibly indicate areas of a richer invertebrate population and biomass as well as intact ecosystem services (Chadwick et al. 2006). Leaf breakdown is an integrative process that is affected by an array of factors, both natural and anthropogenic (Young et al. 2008). The rate of leaf decomposition illustrates the relationship between pivotal aspects of the stream ecosystem, riparian vegetation and microbial and invertebrate activity, which reflects where ecosystem service are intact (Young et al. 2008). Through this experiment, we hope to illuminate the relationship between the urbanization of Rock Island and the degradation of its streams, as well as assess where ecosystem services are intact in the watershed.

Methods

Six different stream sites in the Rock Island watershed system were selected to test leaf breakdown rates. Landowner permission was gained before the experiment progressed. In order to select streams based on health, we arbitrarily chose chloride levels to reflect health due to its detrimental effect on invertebrates, see **Figure 1** (Paul et al 2001). To test stream health, 3 unhealthy sites with elevated Cl, total dissolved solids, and nitrate levels were selected, sites; 3, 12, and 15. Three healthy streams were also selected with the lowest Cl, total dissolved solids, and nitrate levels, sites; 6, 9, and 10, see **Figure 2**. Between all of the sites, temperature, order, visible discharge, pH, and phosphorus levels were relatively constant (see **Table 1**). In order to keep the experiment as controlled as possible, leaf type was standardized among sites (Young et al. 2008). Bags of maples leaves were collected at Augustana's campus on August 29, 2015 and were utilized for this experiment. Maple leaves were chosen because these trees are very representative of the forest cover surrounding the Rock Island watershed (Reisner, personal communication). The leaves were dried and preweighed to 5 grams with a plus and minus weight allowance of 0.1 grams. The leaves were then packed into standard coarse mesh bags in order to prevent inhibition of invertebrate colonization (Benfield 2006). Ten bags were packed per site (for a total of sixty bags), and were spread out in measured increments and tethered to metal rods at each of the six sites. The placement of these bags, on October 6, 2015, were standardized among the sites in order to imitate where leaves naturally accumulate. In this case, riffles were used as the standard location for each bag placement due to their increase in invertebrate density, low sediment deposition, and natural accumulation of leaves (Young et al. 2008). After 2 weeks, on October 20, 2015, 5 bags were removed per site, the contents dried in a 65 degree Celsius oven, and then weighed. After 4 weeks, on November 3, 2015, the last 5 bags were retrieved, once the bags were collected, the leaves were washed of sediment, wrapped in butcher paper, dried in an oven for twenty four hours and then weighed. Mean mass loss was compared among sites by ANOVA to see if decomposition results were significant, calculation of an exponential decay coefficient for the data was by the following equation:

((ln(week 4 mass remaining)/ original mass)/days deployed) (Young et al. 2008, Benfield 2006).

	TDS	Nitrate(NO3)	Chloride(Cl-)	pH	Ammonium(NH4)	Phosphate(PO4)
Healthy	634.83	0.48667	69.913	7.9933	0.10667	0.97667
Standard Deviation	34.84675	0.029938208	16.94247151	0.083843	0.014401646	0.1733547
Unhealthy	946.83	1.4	215.34	7.93	0.12667	0.97
Standard Deviation	30.84489	0.130724477	15.00952389	0.079303	0.002721655	0.082865353

	Avg. Temp.	Avg. Order
Healthy	16.3	2.3
Unhealthy	16.46	2

Table 1 – Streams were compared for total dissolved solids, nitrate, chloride, pH, ammonium, phosphate, temperature, stream order, and visible discharge. The average values and standard deviation of each stream component are shown above for the three healthy and three unhealthy streams. Overall, stream components were very similar except for TDS, chloride, and nitrate.

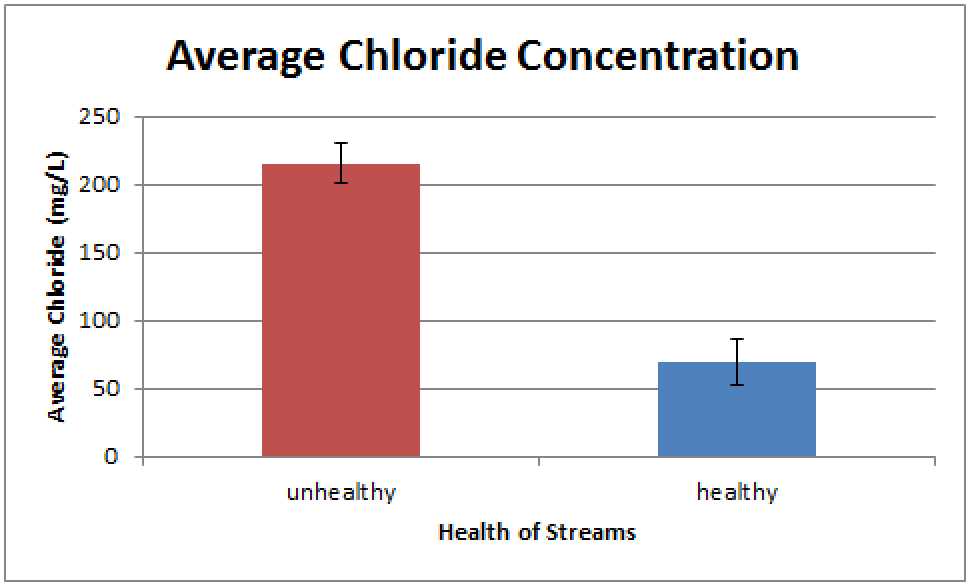

Figure 1 - The chloride levels of three “unhealthy” streams were averaged and compared to the average chloride levels of three “healthy” streams. There is a large and obvious difference in chloride concentration between unhealthy and healthy; therefore chloride level was used as an indicator of stream health.

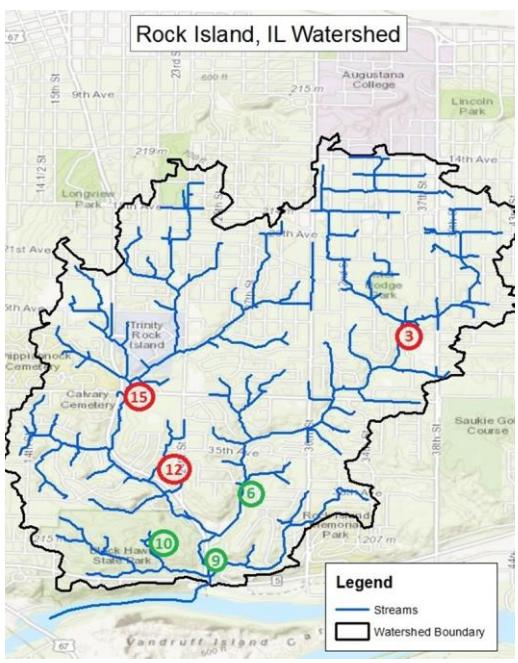

Figure 2 - A layout of the Rock Island Watershed being tested. Sites circled in red were considered unhealthy - 3, 12, and 15. Sites circled in green were considered healthy - 6, 9, and 10. Both sites 9 and 10 reside in Blackhawk State Historic Site. A compass is provided on the right for directionality.

Results

The results of this experiment show that the classified 'healthy' sites produced statistically significant increased rates of decomposition in comparison to the classified 'unhealthy' sites. Site produced a statistically significant effect (Two way ANOVA-Site $p < 0.0009$) suggesting that decomposition could be attributed to site, not chance - see **Figure 3**. After 2 weeks of decomposition the three unhealthy sites had a greater average mass remaining compared to the three healthy sites (T-Test, f=3.432, 4df, $p < 0.003$) - see **Figure 4**. This trend was also observed for the 4 week group, although with less significance (T-Test, f=1.893, 4df, $p < .064$) - see **Figure 5**. The overall comparison of mass remaining due to site selection as well as time can be found again in **Figure 3**, which suggests that site selection (healthy vs. unhealthy) was more significant (Two way ANOVA-Site $p < 0.0009$) than time allowed for decomposition (Two way ANOVA-Time $p < 0.085$). The overall decomposition rates of unhealthy and healthy streams (see **Figure 6**) illustrates that healthy streams produce an increased rate of decomposition and therefore retain less mass after the 2 and 4 week time intervals.

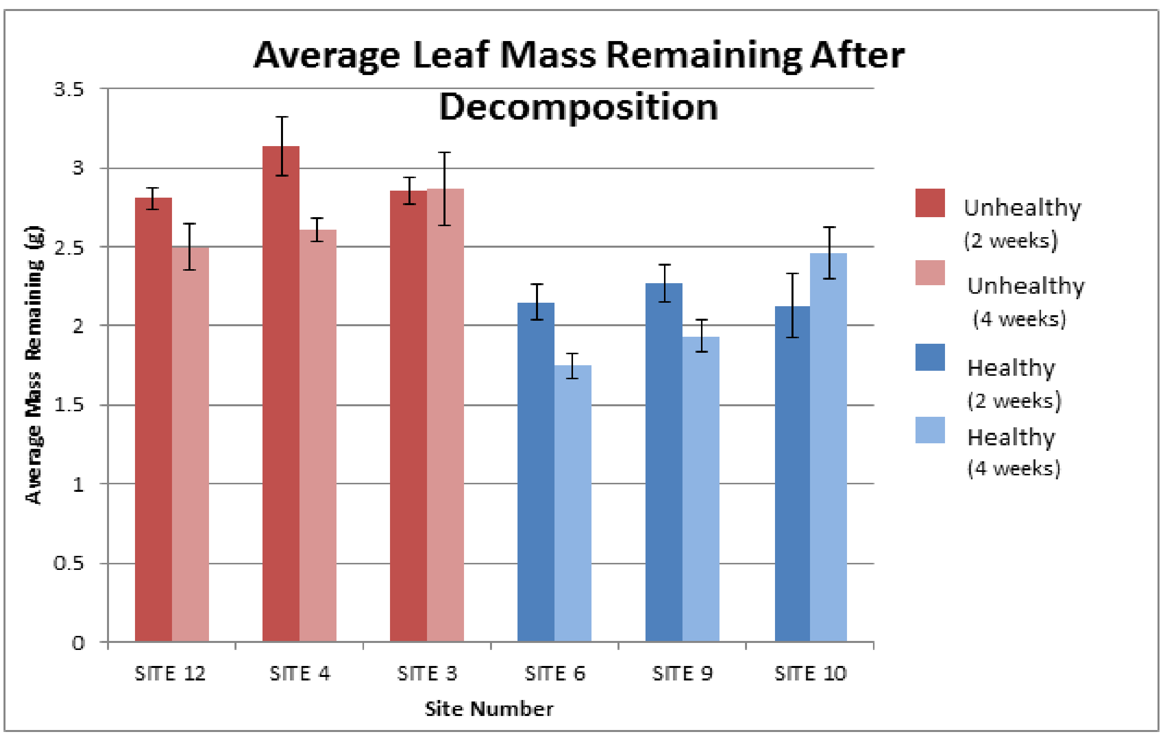

Figure 3 - Average dry leaf mass remaining as a function of site number and time. Site selections are as per figure 2; time left to decompose: either two or four weeks. Each bar represents the mean and standard error of dry mass of five bags harvested after two or four weeks (see legend) of in situ deployment, for

either healthy or unhealthy streams (see legend). Site selection was statistically significant (Two way ANOVA -Site $p < 0.0009$) however, time was not as significant (Two way ANOVA -Time $p < 0.085$). Generally, leaves left in "unhealthy" streams (red) decomposed overall much slower than leaves placed in "healthy" streams (blue).

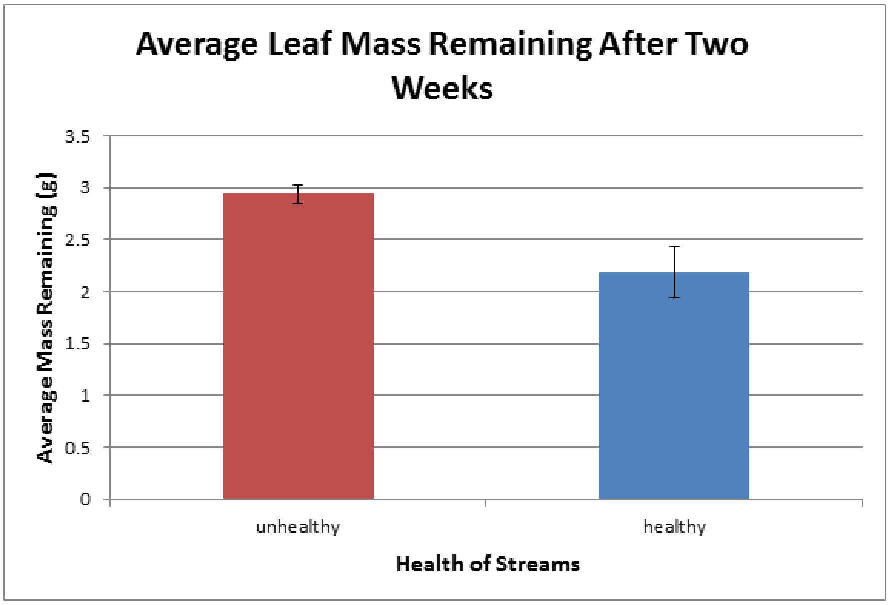

Figure 4 - Average dry leaf mass remaining as a function of site health. Site health determinations are as per figure 1. Each bar represents the mean and standard error of dry mass of five bags harvested after two weeks of in situ deployment. Site was statistically significant (T-Test, f=3.432, 4df, $p < 0.003$).

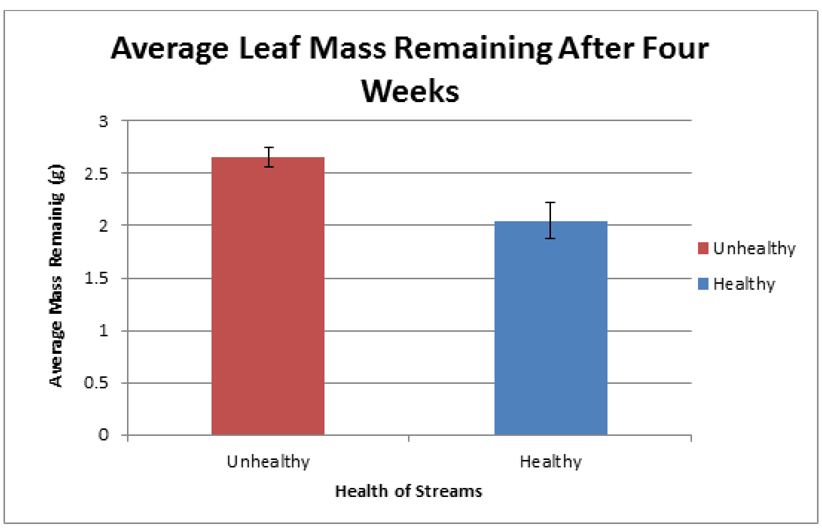

Figure 5 - Average dry leaf mass remaining as a function of site health. Site health determinations are as per figure 1. Each bar represents the mean and standard error of dry mass of five bags harvested after four weeks of in situ deployment. Site was statistically significant (T-Test, f=1.893, 4df, $p < .064$).

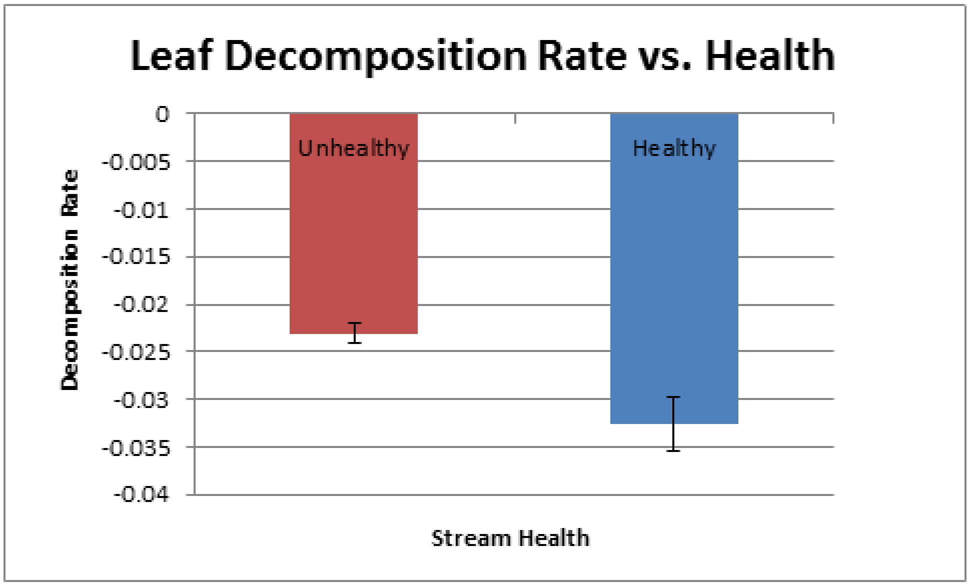

Figure 6 - The rate of leaf decomposition was calculated for each site and averaged per health. The general trend of the data greatly suggests that streams considered "healthy" produced a much higher rate of leaf decomposition in comparison to streams considered "unhealthy". Decomposition rates are negative due to the decrease in mass after the total 28 days in situ deployment, therefore the most negative reflects the greatest decomposition rate in g/day for the entire four week period.

Discussion

Based on the results of this experiment, decomposition rates between healthy and unhealthy streams in the Rock Island Watershed were found to differ significantly. These results appear to be due to the presence (or lack) of invertebrates in the streams. Many studies have suggested that invertebrates play the main role in the decomposition of leaves by acting as the major catalyst of decomposition (Allan et al, 2007, Graca 2001, Tarrant et al 2009). Streams with increased levels of pollutants (Cl) are found to contain fewer essential invertebrate-shredder species (Pascoal et al. 2005). Therefore, from the combination of our experimental data and previous literature, we can conclude that streams considered unhealthy, due to high levels of chloride, produced decreased rates of decomposition most likely due to the decrease of invertebrate presence.

On another note, the unhealthy sites were found to be located closer to impervious surfaces, including roads and parking lots, which in turn increases road salt exposure and thus chloride levels in the streams (Chadwick et al. 2006, Martins et al. 2015). Conversely, two out of the three healthy sites were located in Blackhawk State Park which were further away from any impervious surfaces (and road salt), while the third site was found near a pervious gravel road. In addition, all three healthy sites were surrounded by heavy vegetation. Therefore, our data suggests that there is a negative correlation between distance to impervious surfaces, road salt use, and stream health that could provide an area for further research.

With taking into consideration the previous literature and the results from this study, it is apparent that the streams in Blackhawk State Park are exhibiting qualities that suggest these streams are healthy. These streams are observed to be surrounded by dense vegetation and located away from impervious surfaces. In stark contrast, the sites located closer to impervious surfaces with less riparian vegetation cover exhibit qualities that suggest poor stream health. This trend is also reflected in the decomposition rates discussed above. By conducting this experiment, we have illustrated the trend that urbanization negatively affects streams that drain highly residential areas. By analyzing this data, now we must consider what can be done to fix the degraded areas of this watershed and preserve the ecosystem services that we do have.

One of the most important changes that can be made now to decrease the degradation of streams in the Rock Island Watershed is to better manage the use of road salts. Better management can be achieved first and foremost by decreasing the amount of road salt used overall. Also, by considering other options such as road pre-treatments, the use of salt can be further reduced (Ruth 2003). On a more long-term scale, when planning new road construction, pervious surfaces should be considered as a replacement for concrete and asphalt - this will help reduce high storm flows, etc. Also, increasing riparian vegetation around streams (which would help filter out pollutants and promote invertebrate diversity), should be considered when building new roads and during the repair of roads near streams. Most of all, however, by increasing education about our watershed's health and ecology to the general public we can help maintain the ecosystem services that we do have.

Through conducting this study we have opened the door for further research within the field of leaf decomposition for the Rock Island Watershed. Future studies should observe invertebrate density among the streams in order to find a correlation between invertebrate mass and decomposition rates. In addition, testing leaf decomposition for the remainder of the Rock Island Watershed would be necessary to assess the overall health of the watershed (because we were only able to test 6 streams out of 22). By conducting this research, we can further understand how urbanization affects the water quality and health of the Rock Island Watershed.

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