

**Early to Late Successional Leaf Litter Decomposition Rates in a  
Northern Temperate Stream by *Trichoptera* Larvae.**

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**Abstract**

Freshwater streams depend on organic matter coming from allochthonous input of leaf litter by riparian vegetation. In order for this matter to actively enter the food chain, this organic matter needs to be refined by shredders. The decomposition rates of four riparian trees, *Amelanchier arborea*, *Alnus incana*, *Betula alleghaniensis* and *Acer saccharum*, were studied by feeding caddisfly larvae leaves of each of the four species. A trend of toughness in leaves was observed: late successional leaves are tougher than early successional leaves. Early successional trees had a faster rate of decomposition while late successional species had slower rates. ANCOVA tests were run for the comparison of tree species and weight remaining and day of recollection; yielding the following results: (F-ratio=16.068, df=3, p<0.001) for leaf species and F-ratio= 10.647, df=1, P=0.002) for day. These results suggest that leaf succession has a significant effect on decomposition rates, providing information about which leaves are more efficient for energy input in stream ecosystems.

## **Introduction**

Stream ecosystems are dependent on allochthonous organic matter, often in the form of leaf litter, as a source of energy for their food webs (Wantzen and Wagner, 2006). The processing of organic matter involves biotic activities of microbes, fungi and invertebrates (Robinson and Jolidon, 2005). Aquatic insects are crucial in the refinement of organic matter in freshwater ecosystems because they make up an important part of the energy flow and the cycling of matter (Cummins 1973). The colonization of leaf litter by microbes is important because it makes leaves more nutritious and savoury. It also includes microbes as an important part of shredder diets (Cummins et al. 1973).

Shredders feed on coarse particulate organic matter; they assimilate 40% of it and the remaining 60% is excreted as fecal matter. Decomposers and climate both contribute to the decomposition of leaf litter, however, the quality of the leaves, carbon and nitrogen content and the ratio of carbon and nitrogen are the most significant factors (Perez- Harguindeguy et al. 2004). The ratio of carbon and nitrogen (C:N) in leaf litter affects the excretion of nutrients in their feces by homeostatic regulation (Balseiro and Albariño, 2006). Benthic invertebrate shredders of leaf litter detritus convert coarse particulate organic matter to fine particulate organic matter, which settles in the stream bottom and serves as food

to filtering and gathering invertebrates. Decomposition rates have also been related to acid and water insoluble condensed tannins, calcium (Ca), lignin and phenolic nitrogen (N) (Valachovic 1998).

Tree succession is an important factor in shredding preferences. Early successional tree species allocate greater energy amounts to growth and a smaller portion of energy is dedicated to defense mechanisms. Late successional species dedicate more energy to defense mechanisms like tough texture and high tannin content and less to growth. Late successional leaves more tannin and are tougher. These leaves have a higher C:N and C:lignin ratio than early successional leaves and these ratios have been known to affect the rate of decomposition by making late successional leaves less appealing to shredders (Mingione 2003).

The sole shredder to be used in this study will be caddisfly larvae. Caddisfly larvae, order Trichoptera are important shredders in temperate streams that feed on aquatic and terrestrial detritus. Nitrogen content of the leaves is an important factor since invertebrate shredders do homeostatic regulation of N and affect N dynamics in nutrient poor streams (Balseiro and Albariño, 2006). The study of aquatic insects is of extreme importance because they are biological

indicators. Natural undisturbed systems are rich in diversity of aquatic insects. Many studies of decomposition rates have been conducted in temperate regions, (Wantzen and Wagner 2006, Robinson and Jolidon 2005, Cummin et.al. 1973), but not many done with shredding caddisfly larvae. Leaf succession and decomposition rate has been recently related and there are only a few studies on this (Covich 1988, Mignione 2003). This study will provide new insight in the effect of succession in riparian zones.

The goal of this study was to determine if there is a significant difference between tree succession and decomposition rates of leaf litter in streams. Four native deciduous species of Northern Michigan were used to analyze decomposition rates by feeding the leaves to *Trichoptera* larvae. Speckled Alder (*Alnus incana*) and Downy Serviceberry (*Amelanchier arborea*) are early successional species. A mid- to late successional species is represented by Yellow Birch (*Betula alleghaniensis*); a tree that has several anti-herbivore defences like chemicals and tannins. Sugar Maple (*Acer saccharum*) is a late successional hardwood tree species and is very widespread in the Michigan area. *A. saccharum* is a shade tolerant tree that is very successful in the colonization of newly disturbed zones and has low mortality in the Michigan North Woods (Kobe et. al. 1995). Fast growth of early successional species after a disturbance affects the

energy dynamics in freshwater streams because energy inputs of leaf litter differ (Covich 1988). It is important to know the decomposition rate of *A. saccharum*, observed as common specie in riparian zones on the University of Notre Dame Environmental Research Center (UNDERC), since it may affect the energy needed in the stream from allochthonous input. I hypothesize that the early successional leaves, *A. incana* and *A. arborea* will have a faster decomposition rate because of higher nutritional value than later successional species, which contain more chemical defenses to predation and are commonly tougher. Therefore following the early successional trees, the mid to late species, *B.alleghaniensis*, will have a faster decomposition rate than the late successional *A. saccharum*.

## **Methods and Materials**

### *Study site*

Collection of caddisfly larvae was done in Plum Creek and Tenderfoot Creek, a northern temperate stream in the UNDERC- East property located in Goebic Co, Michigan and Vilas Co. Plum Creek is a first order outflow stream and Tenderfoot Creek is a low gradient second order stream (Figure 1). The collection was done in the beginning of June, when caddisfly larvae are not likely

to be found because of warm temperatures. Nevertheless caddisflies were found this year until early July. The natural sediments of both streams consist mainly of muck (fine organic matter). The collection was done by wading through the stream and placing caddisflies in plastic containers. The caddisflies were then taken to the laboratory and placed in plastic containers in cold temperature incubators with an air pump and leaf litter for food. The caddisflies used in the experiment were identified to genus and found to belong to the same Family *Limnephilidae*, however, they did not all belong to the same genera. Genus *Onocosmoecus* was found in Plum Creek and Genus *Limnephilus* in Tenderfoot Creek. Nevertheless the Family *Limnephilidae* share common characteristics, for example univoltinism and shredding feeding habits.

#### *Litter Collection and Preparation*

Leaf litter collection, of the four riparian species, was done in various sites surrounding Tenderfoot Creek. Dry leaves from the forest floor were taken to the laboratory and selected for their integrity, (non-broken or pierced). Sixteen leaf discs for each species with a diameter of 3 centimeters were cut. Five other leaves of each species were used for toughness analysis with a Push and Pull Fruit Penetrometer, model F01 (500g X 5g) of the International Ripening Co. Three readings per leaf were done by puncturing the leaf horizontally with a 1 millimeter metal needle, for an average per leaf and then per species with the

five leaves. A color code was designed for the identification of leaves to know the order of collection from the artificial streams. Black= 1<sup>st</sup> week, Red=2<sup>nd</sup> week, Green= 3<sup>rd</sup> week and Purple= 4<sup>th</sup> week. Each leaf disk was marked with a color and weighed using a mass weight balance.

### *Artificial Streams*

Four leaves of each species were placed in a cage with four caddisfly larvae in each of the artificial streams. The cages were constructed out of Plexiglas sheets pasted with silicone; the bottom had sand and little stones attached for the caddisflies to have something to hold on to. The ends of the cages were closed with a mesh with holes of 1000 micrometer and pasted with hot glue. Four replicate streams were used for each of the four tree species. The caddisflies were starved for 24 hours previous to the experiment. The experiment ran for a week, every other day a leaf and a caddisfly were taken out. The leaf was dried at room temperature for 24 hours and the final weight was recorded. The streams were checked to know if they were running well and if there were any dead caddisflies two times a day for the whole week; if a caddisfly was found dead, it was replaced with a new one.

### *Data Analysis*

The proportions for weight remaining, weight remaining/initial weight, of each leaf were calculated and with these a mean per species and day was made. These results were graphed and an exponential regression was performed for these results. In order to calculate the decomposition rate, a standard negative exponential model was used, where  $m_t$  is final mass,  $m_0$  is initial mass and  $t$  is time. The  $k$  value of this regression is the rate of decomposition according to the equation:  $m_t = m_0 e^{-kt}$ .

Statistical analysis was conducted with SYSTAT 12. Shapiro-Wilk test for normality was run for each species. Analysis of covariance (ANCOVA) was used to compare leaf weight change and day of recollection for all species. In order to enhance the robustness of the ANCOVA's an arcsine transformation was performed. The factor was leaf specie, the response variable was the arcsine transformation of weight proportion remaining and the covariate was day.

## Results

### *Leaf species vs. Caddisfly decomposition rate*

For all tree species a negative correlation was found for decomposition rates. The plots of weight proportion lost vs. time show the negative exponential curve (Figure 2). The early successional species *Alnus incana* and *Amelanchier arborea* had the highest decomposition rate  $k= 0.328$  and  $k= 0.301$  respectively. The mid-to late successional species, *Betula alleghaniensis*, and the late successional species, *Acer saccharum*, had slower decomposition rates:  $k= 0.091$  and  $k= 0.07$  respectively. For most leaf species the mass remaining decreased exponentially as a function of time.

The ANCOVA analysis for weight proportion remaining illustrated a significant difference between all leaf species studied (F-ratio=16.068, df=3,  $p<0.001$ ). A significant difference was also found for the ANOVA between weight proportion remaining and day (F-ratio= 10.647, df=1,  $P=0.002$ ).

### *Leaf Toughness Analysis*

The toughest leaf species was *A. incana* with a mean of  $58\text{g/mm}^2$ , *A. saccharum* had a mean toughness of  $57\text{g/mm}^2$ . *B. alleghaniensis* followed with toughness of  $52\text{g/mm}^2$  and *A. arborea*  $51\text{g/mm}^2$  (Figure 3).

## Discussion

The comparison between leaf succession and decomposition rates in a northern temperate stream support a relationship between leaf succession and decomposition rate; the level of succession had a negative impact on decomposition rates. The most efficient decomposition was observed for *A. incana* and *A. arborea* the early successional species. The mid-to late successional species, *B. alleghaniensis*, had a slow rate of decomposition but the slowest rate was observed for *A. saccharum*. The mean weight loss of all species in comparison can be observed (Figure 4). The ANCOVA results for species and weight remaining are statistically significant, indicating a difference between the species; the results for the comparison to day of collection are also statistically significant. I was interested in the analysis of day of recollection because I wanted to know if the leaves were decomposed faster as the days went by and leaves were moister; also for the comparison of time for all species analyzed with the ANCOVA. The weight loss mean of the leaves increased as time went by for the early successional species, *A. incana* and *A. arborea* ; *B. alleghaniensis* and *A. saccharum* had an almost constant mean of weight loss for the eight days. An explanation for this could be that as the leaves were longer in the stream, they were softer and easier to chew. Caddisflies were starved 24 hours prior to the experiment and this could result in a bigger need for food in the first days of the experiment. As for the mid- to late and late successional species, an explanation

for the constant mean weight proportion lost could be that less nutritious leafs are less appealing and their palatability does not increase with moisture; nevertheless further studies (as will be discussed further on) would be necessary to address this issue.

*A. incana* leaves are the toughest in accordance to the toughness analysis conducted on the leaf litter collected. I hypothesized that leaf toughness makes them less palatable however, although *A. incana* leaves where the toughest, the toughness did not appear to have reduced palatability as it had the fastest decomposition rate. Leaf succession could be an explanation for this, since *A. incana* leaves are have more nutritional value and less chemical defences even by being toughest. The other early successional species, *A. arborea*, did not follow this trend. The late successional species, *A. saccharum*, was the next in toughness; this in combination with chemical defences could be the reason for them to be unappealing to *Trichoptera* larvae. *B. alleghaniensis* is tougher than *A. arborea* but not as much as *A. saccharum*; this supports my hypothesis, the mid-to late successional species has an intermediate toughness and decomposition rate between early and late successional species. The least tough leaf specie was *A. arborea* a more palatable leaf in accordance with the decomposition rate results;

this combination of less toughness and nutrition could be the determining factor in the preference of this specie over mid- to late and late successional species.

The quality of litter, in terms of nutrients and especially C:N, as well as climatic factors were responsible for regulating leaf litter decomposition rates (Zhang et. al. 2008). The results obtained suggest that, *A. saccharum*, the most common riparian species has the slowest rate of decomposition. The succession of forests in riparian zones could have a negative effect on decomposition rates if late successional trees, like *A. saccharum*, replace early successional species. Thus making them the major source of allochthonous input for the energy flow of streams (Covich 1988).

A study by another UNDERC student on decomposition rates found a statistically significant relationship between leaf succession and decomposition rates in a study with crayfish. The study was conducted with three of the species used in my experiment: *A. arborea*, *B. alleghaniensis* and *A. saccharum*; her findings were like the ones in this study: decomposition rates increased with decreasing tree succession. (Mignione 2003). To my knowledge no publications on this relationship in stream ecosystems has been done; therefore more studies

on this subject would be needed to know how stream energy flow is functioning in forests where leaf succession in riparian zones is changing.

Future studies would be needed in order to compare decomposition rates of leaf litter in a stream without the presence of shredders. This control group was not tested. Other modifications would be more replicates and more days of study as well as a more consistent method of measurement. One or more measurements per day would be necessary. An analysis of gut contents in the caddisflies could be of use in the interpretation of leaf matter consumed.

Figures

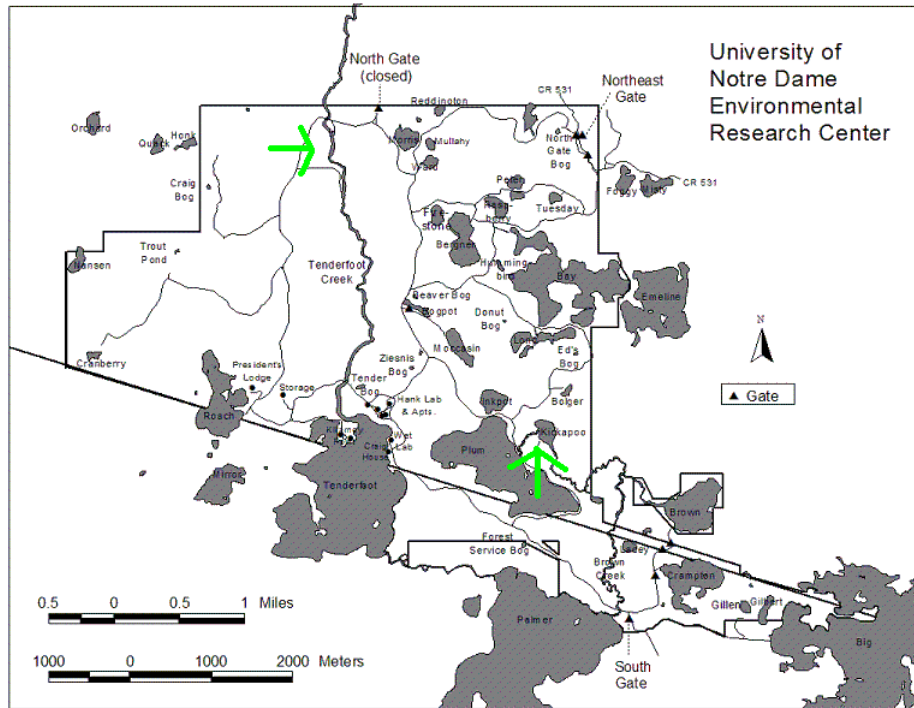


Figure 1: The top arrow indicates the area in Tenderfoot Creek where caddisflies were collected. The bottom arrow shows Plum Creek between Plum and Kickapoo Lakes.

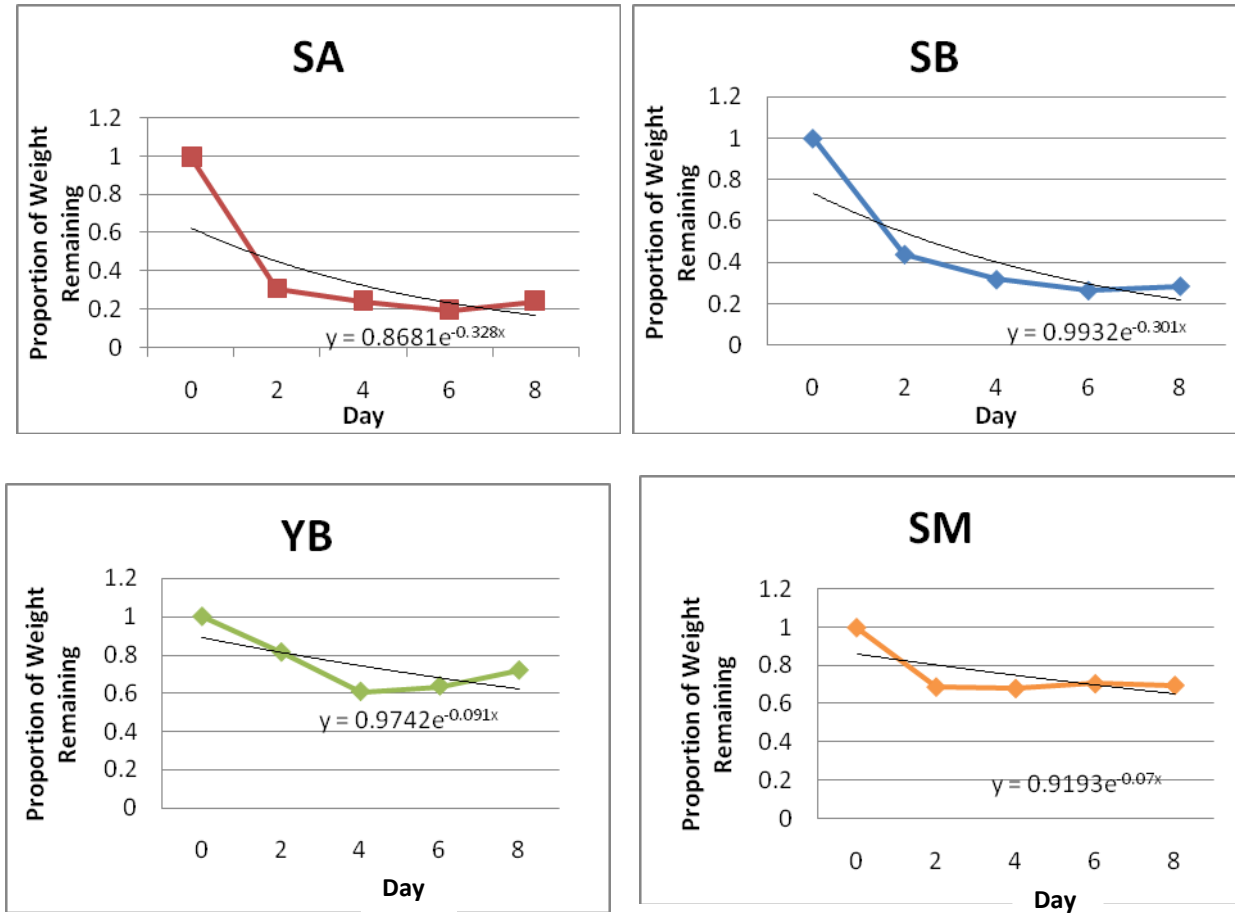


Figure 2: Graphs for the relationship by leaf specie of weight proportion of leaf remaining and day of measurement with the exponential regression and showing the decomposition rate,  $k$  as  $m_t = m_0 e^{-kt}$ . Each graph is titled with each specie; SA= Speckled Alder (*Alnus incana*), SB= Downy Serviceberry (*Amelanchier arborea*), YB= Yellow Birch (*Betula alleghaniensis*) and SM= Sugar Maple (*Acer saccharum*).

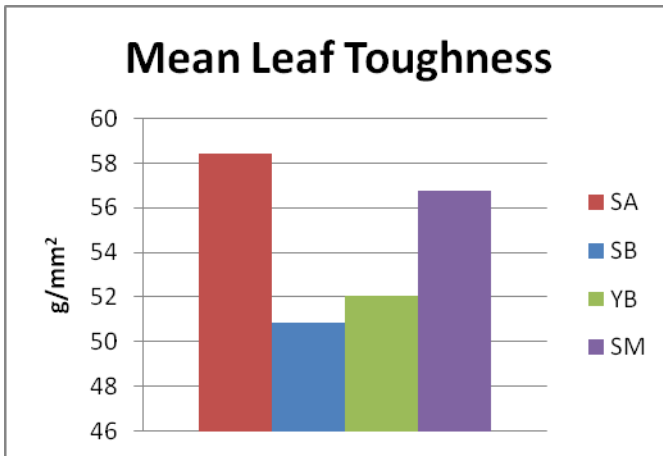


Figure 3: Bar graph of the mean of leaf toughness per specie in units of g/mm<sup>2</sup>. The legend gives the each species a color, and the abbreviations mean the following: SA= Speckled Alder (*Alnus incana*), SB= Downy Serviceberry (*Amelanchier arborea*), YB= Yellow Birch (*Betula alleghaniensis*) and SM= Sugar Maple (*Acer saccharum*).

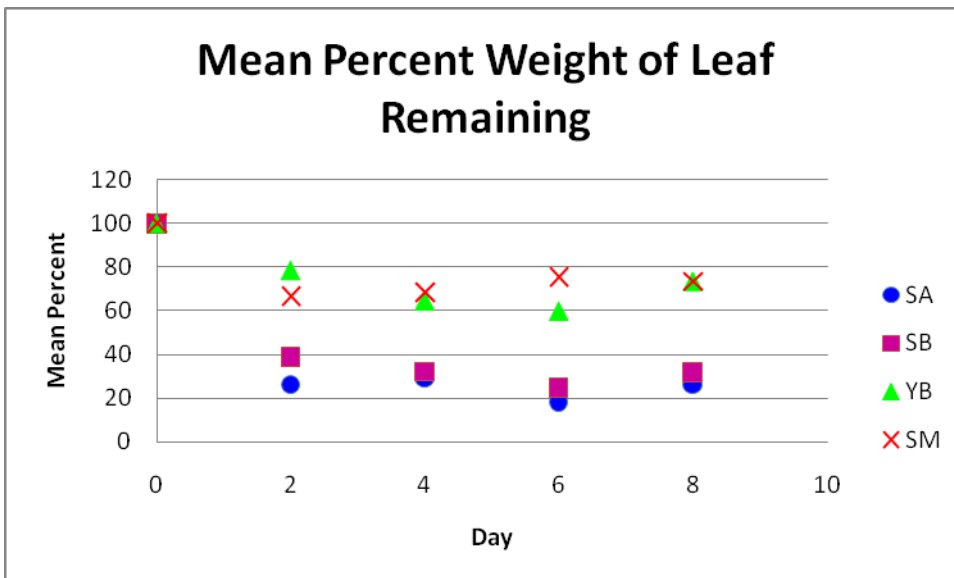


Figure 4: Comparison between all tree species as the leaf weight changes through time. Abbreviations follow the trend used in previous graphs.

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