Differential Leaf Decomposition in Pools and Riffles of a Northern Michigan Stream

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ABSTRACT

Rates of decomposition of three leaf species were determined experimentally in riffle and pool sections of a north temperate stream, Tenderfoot Creek, in Gogebic Co., Michigan. The three species studied were sugar maple (*Acer saccharum*), speckled alder (*Alnus rugosa*), and sweet gale (*Myrica gale*). The course of decomposition was measured over a five week interval from June 6, 1994 to July 15, 1994.

The leaves in the riffle packs decomposed from 75% to 98.8% dry mass within the two week interval, and eventually each species decomposed approximately 99% at the end of the four week interval. The pool packs, however, only decomposed from 55% to 75% in the two week interval and needed a total of five weeks to decompose from 90% to 98%.

Insect colonizers also differed between the riffle and pool areas. In the riffle, the major colonizers were large insect larvae: net spinning caddis flies (Trichoptera: *Hydropsychidae*) and dragonflies (Odonata). In contrast, the nearly exclusive colonizers of the pool packs were midge larvae (Chironomidae: *Chironomini*). Such differences in colonization may be due to the different substrata and habitats offered by riffles and pools.

INTRODUCTION

The diversity of organisms inhabiting a woodland stream is greatly dependent on the availability of key organic nutrients found there. One of the major sources of stream nutrients has been organic material from the canopy of the riparian vegetation (Anderson and Sedell 1979, Cummins et al. 1973, Reice 1974). Leaves contain the bulk of these riparian nutrients; therefore, leaf litter is an important factor in the diversity of the stream's inhabitants (Anderson and Sedell 1979, Cummins et al. 1973, Cummins et al. 1989, Lamberti and Gregory 1989, Reice 1974).

Upon entering the water, leaves begin to decay. The first stage of decay is leaching, where organic nitrogen and carbon compounds are dissolved (Petersen et al. 1989, Reice 1974, Short and Maslin 1977). Most of this leaching occurs within the first 48 hours in the water (Anderson and Sedell 1979, Reice 1974, Short et al. 1980).

The remaining leaf litter is then colonized by microorganisms, such as aquatic fungi and bacteria (Cummins et al. 1989, Lamberti and Gregory 1989, Petersen et al. 1989). This process is called "conditioning". Microorganism colonization makes the leaf litter nutritionally beneficial to macroinvertebrates, such as insect larvae. These macroinvertebrates are called shredders, and they accelerate the decay process (Reice 1974, Short and Maslin, 1977).

These shredders will graze on any conditioned leaf litter (Cummins et al. 1973), but the differential effect comes from the fact than the microorganisms will selectively colonize one species over another (Short et al. 1980). This selective colonization has a direct effect on the overall decomposition rate (Cummins et al. 1989).

In order to maximize microbial growth, the leaves must be kept in an aerobic environment. This is also essential for the survival of the shredders during feeding (Anderson and Sedell 1979, Cummins et al. 1989). It is for this reason the *in situ* leaf pack method of experimental sampling has been the traditional method for this type of study (Anderson and Sedell 1979, Benfield and Webster 1985, Cummins et al. 1989, Gurtz and Tate 1988, Reice 1974). In this type of study, leaf material is placed in the water in a mesh pouch. This container allows retention of the leaf material in a current, yet also maintains the aerobic environment required as well as allowing free passage of macroinvertebrates (Benfield and Webster, 1985).

There are countless experiments, some referenced here, of decomposition experiments in riffle areas. These riffle areas are shallow and fast moving, and therefore provide an easy access, aerobic environment. Strangely, few experiments have been found researching leaf decomposition in pool areas of streams.

The object of this study is to compare the decomposition of leaves commonly used in this type of study in both riffle and pool areas of a stream. The macroinvertebrate colonization will also be compared. Leaves in the pool are expected to decay at a slower rate than those in the riffle. This is expected due to the variety of habitats offered by the riffle, thus supporting a diversity of organisms that will speed the decomposition process.

MATERIALS AND METHODS

Tenderfoot Creek is located in Gogebic Co., in the Upper Peninsula of Michigan in the United States. It originates in Tenderfoot Lake and flows north, through the University of Notre Dame Environmental Research Center and eventually empties into Lake Superior.

Leaves of three species of trees local to the riparian zone of Tenderfoot Creek were selected for study. The three species chosen were sugar maple (*Acer saccharum*), speckled alder (*Alnus rugosa*), and sweet gale (*Myrica gale*). The rates of decomposition of each was studied using the commonly used *in situ* method of leaf decay study.

Leaves of each species were collected on June 1, 1994 through June 5, 1994, before abscission from the riparian zone of Tenderfoot Creek. The leaves were dried in an oven for 24 h at 40°C to remove moisture. They were then assembled into individual packs for each species, weighing about 5 g each (dry mass). The leaves were then rewet to prevent crumbling and placed in packs. The packs were constructed of 10 mm plastic mesh gutter-guard material. Each pouch was 10 cm x 15 cm and was secured with a wire twist tie to prevent opening once in the water. Each pack was labeled to show species, date to be collected, and number. Each pack was secured to a clean rock with 2 rubber bands and placed at the bottom of the stream in a randomized block design on June 6, 1994. In both the riffle and pool areas, the matrix placed neighboring packs 1.5 m apart and 2 m upstream from the next pack. Extra packs of each species were included to avoid unplanned losses.

In the riffle, the first row of the randomized block design rested 60 m from the start of the riffle. Throughout the sampling area, the average width of the channel was 11 m and the average depth was 35 cm midchannel.

The pool area was located 160 m downstream from the riffle sample area. The sampling area was placed 15 m downstream from the beginning of the pool area. Through the sampling area, the average width of the channel was 38m and the average depth, midchannel, was 64 cm.

Samples of the riffle area were taken at 2 and 4 week intervals. The pool was sampled at 48 h, 2, 4, and 5 weeks. Riffle samples consisted of 2 packs per species. Pool samples consisted of 4 packs per species. In both areas, sampled packs were rinsed in a 250 micron sieve to separate debris. Macroinvertebrates were removed and preserved in 75% ethanol for taxonomic identification. Leaf matter was dried for 24 h at 40°C to extract moisture then was weighed to the nearest 0.01 g. Decomposition rates were determined using an exponential model of decay of the form $Y_f = Y_o e^{-kt}$, which is often used in leaf decomposition comparison (Benfield and Webster 1985, Short et al. 1980).

RESULTS

The data are presented in Tables 1-6, showing the individual pack data for each collection at each interval. Packs designated as (-----) were lost in the stream, and no data was recorded. Figures 1 and 2 show the relative decay of each species in both the riffle and pool areas. Figures 3, 4, and 5 show the different rates of decomposition of each species between the riffle and pool samples. The average water temperature of the water over the 5 week period was 19°C.

The leaves in the 48 h sample all showed considerable mass loss. This loss ranged from 44.6% loss in sweet gale to 22.2% loss in speckled alder. Sugar maple was intermediate, with a loss of 37.9%.

The 2-14 day decomposition showed increased decay in each species. In the pool, Sugar Maple decayed the fastest in this period, with total loss at 74.1%. Sweet gale decayed the slowest, with total loss now equaling 69%. Speckled alder decayed midline, with total loss at 53.7%. In the riffle, each species decayed much faster over the 0-14 day interval. Speckled alder decayed the least, with 74.9% loss; followed by sugar maple, with 93.75% loss, and sweet gale, with 98.8% loss.

The 14-28 day decay period followed the previous pattern of decay. In the pool, sugar maple and sweet gale decayed the most with about 92% mass lost, yet speckled alder decayed less with about 85% decay. In the riffle, each species had lost nearly 99% of its mass. Only woody stems were left in the packs.

At 35 days, the pool species nearly reached the level of decay seen in the riffle 7 days prior. Speckled alder and sweet gale lost a total of 92% while sugar maple bottomed out at 98.3% decay.

Table 7 shows the distribution of insect larvae among the different species in different locations. Each species in the pool was almost exclusively colonized by midge larvae (Chironomidae). Sugar maple was equally dominated by *Chironomini tribelos* Townes, C. *polypedilum* Kieffer, and C. *paratendipes* Kieffer. Speckled alder was primarily dominated by C. *tribelos* Townes. Sweet gale was primarily dominated by C. *paratendipes* Kieffer.

The riffle species were relatively devoid of midge larvae, with only an occasional C. *polypedilum* Kieffer. Mostly these were dominated by larger shredders. These included stonefly larvae (Plecoptera) and diverse dragonfly larvae (Odonata). The most dominant riffle shredders, however were the net spinning caddisflies, Trichoptera: *Hydropsyche* spp.

DISCUSSION

The results of the leaf decomposition show a marked difference in decomposition rates between the riffle and pool areas. Figures 3-5 show that the rate of decomposition for each species of leaf is much slower in the pool area. The rates of riffle decay for each species were, in general, at least double those of the pool packets.

In the two week interval, the following decay constants (riffle, pool) were observed: sugar maple (.197, .096), speckled alder (.099, .055), sweet gale (.314, .083). The four week interval showed the same trend: sugar maple (.197, .090), speckled alder (.136, .068), sweet gale (.222, .088).

Obviously, there was a marked distribution of species between the riffle and pool areas. The dominance of larger macroinvertebrates in the riffle, such as Plecoptera, Odonata, and Trichoptera is expected, since these are considered "clingers" -- larvae that require a hard substrate to cling to in order to avoid being swept away by the fast currents (Merritt and Cummins, 1979). The dominance of *Chironomidae* in the pool also agrees with their label of "burrowers". Chironomids burrow into the fine sand and sediments of pools and other slow moving aquatic areas (Merritt and Cummins, 1979). These findings are concurrent with other studies of chironomid and *Hydropsychidae* distributions through riffles and pools (O'Connell and Campbell 1953). *Polypedilum* is noted for living in silty, sandy areas with sources of dense vegetable and wood substrate (Shadin 1956), which describes the condition of the pool substratum.

Also interesting was the fact that several chironomids were found in the riffle, yet it was rare to find the large riffle species in the pool. This is explained by the fact that riffles offer a wide range of habitats, while the pool only provides relatively uniform substratum. Thus, pool species are capable of migrating to the riffle, where they can colonize a free niche, but riffle species migration to the pool is rare (Edington 1968).

Other factors may have influenced the decomposition as well. Nitrate and phosphate levels drop significantly when water moves through a riffle system (Neel 1951). This has two implications. First, these nutrients support a large microorganism population in the riffle, increasing food sources for a more diverse range of macroinvertebrate shredders. Second, since the nutrient levels are low leaving the riffle, not as many nutrients are released into the pool. Thus, the microorganism, and therefore the macroinvertebrate, population is limited. It has also been shown that, in Midwestern pools, decaying leaves decrease the oxygen levels in water (Schneller 1955, Larimore et al. 1959). This decrease in oxygen may further limit macroinvertebrate colonization, thus slowing the rate of decomposition in pools.

This experiment merely provides baseline data and the possibility of future experiments. Investigations of water velocity, oxygen, nitrate and phosphate levels, as well as a more detailed, finely monitored experiment are suggested. Experiments such as these would help to further the understanding of leaf litter nutrient release in the stream ecosystem.

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Figure 1: **Decomposition of Each Species in a Riffle**

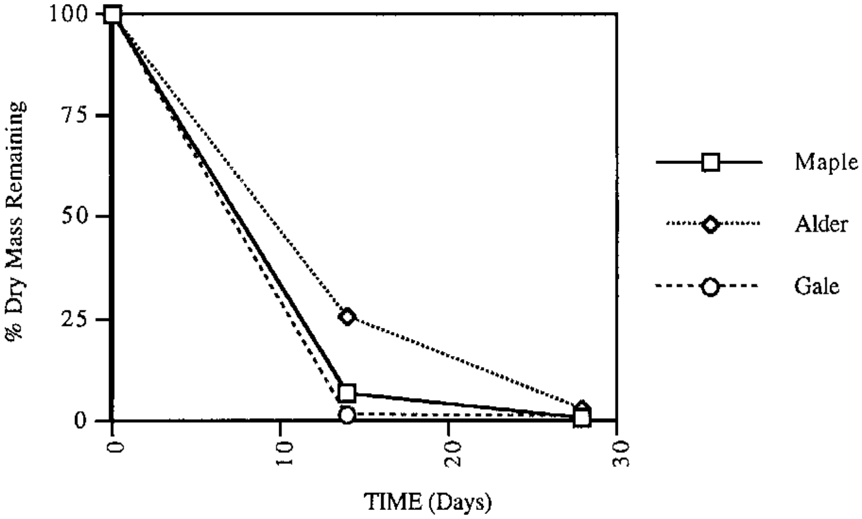

Figure 2: **Decomposition of Each Species in a Pool**

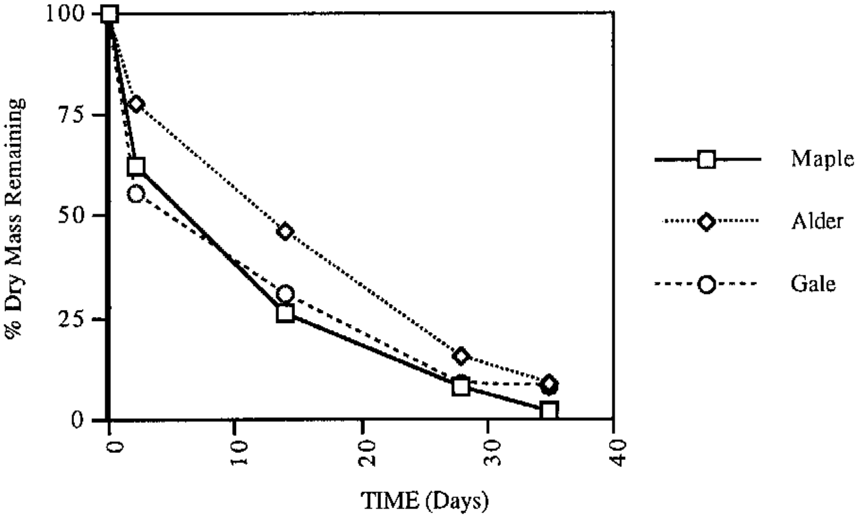

Figure 3: **Decompositions of Pool and Riffle Speckled Alder**

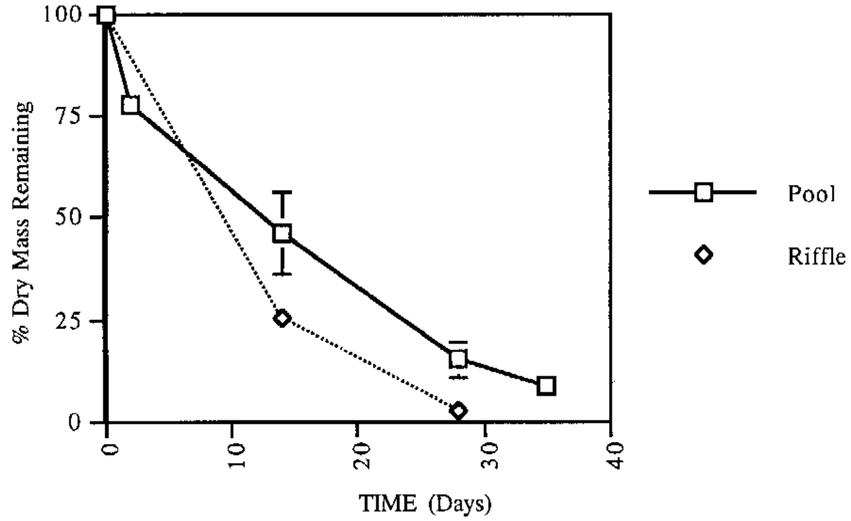

Figure 4: **Decompositions of Pool and Riffle Sugar Maple**

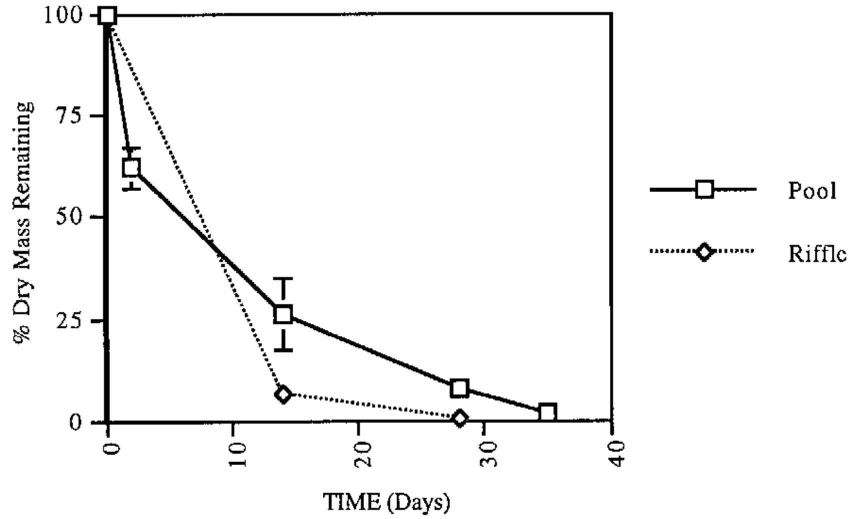

Figure 5: **Decompositions of Pool and Riffle Sweet Gale**

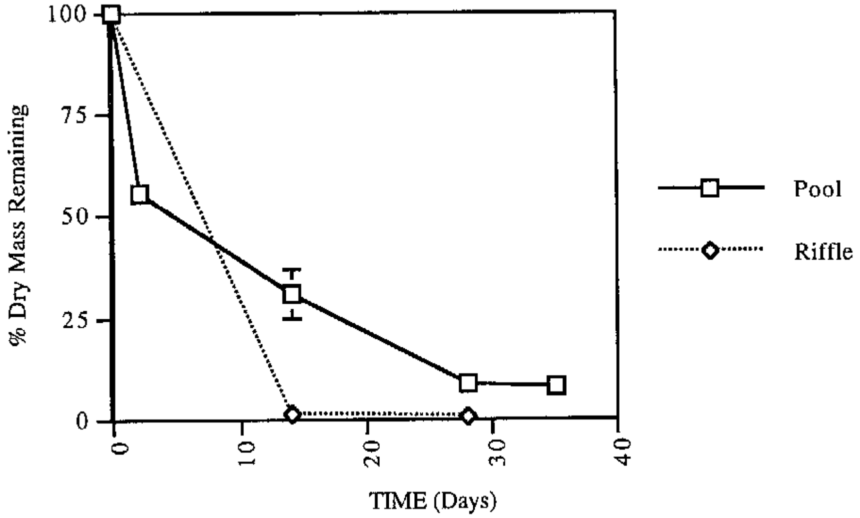

Table 1. Starting and ending masses of leaves after 48 h in the Pool area (June 8, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	4.99	3.37	67.5 +/- 4.9
2	5.01	3.31	66.1 +/- 4.9
3	5.02	2.80	55.8 +/- 4.9
4	4.98	2.94	59.0 +/- 4.9
		Average % Remaining:	62.1
Speckled Alder			
1	4.96	3.84	77.4 +/- 2.9
2	5.00	3.67	73.4 +/- 2.9
3	5.03	4.09	81.3 +/- 2.9
4	5.01	3.97	79.2 +/- 2.9
		Average % Remaining:	77.8
Sweet Gale			
1	5.03	2.80	55.7 +/- 1.8
2	5.00	2.87	57.4 +/- 1.8
3	4.97	2.64	53.1 +/- 1.8
		Average % Remaining:	55.4

Table 2. Starting and ending masses of leaves after 2 w
in the Pool area (June 20, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	5.02	1.59	31.7 +/- 8.7
2	5.01	1.45	28.9 +/- 8.7
3	4.97	0.55	11.0 +/- 8.7
4	4.96	1.58	31.9 +/- 8.7
		Average % Remaining:	25.9
Speckled Alder			
1	5.00	3.18	63.6 +/- 10.2
2	5.03	2.06	41.0 +/- 10.2
3	5.01	1.89	37.7 +/- 10.2
4	5.00	2.14	42.8 +/- 10.2
		Average % Remaining:	46.3
Sweet Gale			
1	4.99	1.12	22.4 +/- 6.1
2	5.02	1.82	36.3 +/- 6.1
3	4.98	1.71	34.3 +/- 6.1
		Average % Remaining:	31.0

Table 3. Starting and ending masses of leaves after 2 w in the Riffle area (June 20, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	5.01	0.36	7.1 +/- 0.9
2	5.00	0.27	5.4 +/- 0.9
		Average % Remaining: 6.3	
Speckled Alder			
1	5.03	1.94	38.6 +/- 13.5
2	4.98	0.58	11.6 +/- 13.5
		Average % Remaining: 25.1	
Sweet Gale			
1	4.97	0.06	1.2
		Average % Remaining: 1.2	

Table 4. Starting and ending masses of leaves after 4 w in the Pool area (July 6, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	5.01	0.36	7.2 +/- 3.6
2	4.98	0.60	12.0 +/- 3.6
3	4.99	0.51	10.2 +/- 3.6
4	4.97	0.13	2.6 +/- 3.6
		Average % Remaining:	8.0
Speckled Alder			
1	5.02	0.70	13.9 +/- 4.3
2	5.00	0.70	14.0 +/- 4.3
3	5.00	1.15	22.0 +/- 4.3
4	4.99	0.52	10.4 +/- 4.3
		Average % Remaining:	15.1
Sweet Gale			
1	4.97	0.32	6.4 +/- 1.6
2	4.98	0.49	9.8 +/- 1.6
3	5.03	0.49	9.7 +/- 1.6
		Average % Remaining:	8.6

Table 5. Starting and ending masses of leaves after 4 w
in the Riffle area (July 6, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	5.00	0.02	0.4
2	5.03	0.02	0.4
		Average % Remaining: 0.4	
Speckled Alder			
1	5.00	0.06	1.2 +/- 1.0
2	5.03	0.16	3.2 +/- 1.0
		Average % Remaining: 2.2	
Sweet Gale			
1	4.98	0.01	0.2
		Average % Remaining: 0.2	

Table 6. Starting and ending masses of leaves after 5 w
in the Pool area (July 13, 1994)

Leaf Pack Number	Starting Mass (grams dry wt.)	Final Mass (grams dry wt.)	% Remaining
Sugar Maple			
1	5.01	0.13	2.6 +/- 0.6
2	4.96	0.05	1.0 +/-0.6
3	4.99	0.10	2.0 +/- 0.6
4	5.02	0.06	1.2+/- 0.6
		Average % Remaining:	1.7
Speckled Alder			
1	5.01	0.45	8.9 +/- 3.7
2	4.99	0.11	2.2 +/- 3.7
3	5.03	0.57	11.3 +/- 3.7
4	5.00	0.55	11.0 +/- 3.7
		Average % Remaining:	8.4
Sweet Gale			
1	5.02	0.42	8.4 +/- 1.8
2	4.97	0.49	9.9 +/- 1.8
3	4.99	0.28	5.6 +/- 1.8
		Average % Remaining:	8.0

Table 7: Distribution of insect larvae based on species and location. Figures represent the total number of each class of organism collected over the entire colection period.

	C. Tribelos	*C. Polypedilum*	*C. Paratedipes*	*Plecoptera*	*Odonata*	*Hydropsyche spp.*
Pool						
Sugar Maple	32	27	39	0	0	0
Speckled Alder	96	30	15	0	1	0
Sweet Gale	33	12	75	0	2	0
Riffle						
Sugar Maple	2	5	0	18	14	49
Speckled Alder	0	6	1	24	13	56
Sweet Gale	0	4	0	12	8	72