

Effects of Varying Nutrient Levels on Summer-Input Speckled Alder Leaf Decomposition

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ABSTRACT

Summer-input leaf decomposition constitutes a major energy source for freshwater streams. The effects of increased nutrient supply on fresh speckled alder leaves were studied. Leaf packs containing approximately 5 grams of leaves each were placed into a northern Michigan stream, and subjected to control, low, and high nutrient conditions for 42 days. Leaves in low nutrient packs decayed most rapidly ($k=0.0492$) and high nutrient packs decomposed most slowly ($k=0.0427$). Macroinvertebrate numbers for all treatments were higher on day 14 than on day 42. Chironomids and Trichoptera were very plentiful throughout the study, while the number of Plecoptera dropped rapidly between days 14 and 42. Although macroinvertebrates were more abundant in packs early in the study than at the end, the number of macroinvertebrates per gram of dry leaf mass steadily increased with time. Finally, as the number of macroinvertebrates declined, so did the number of taxa found within the packs.

INTRODUCTION

The decay of coarse particulate organic matter is a vital process in stream ecosystems. The energy released as a result of the breakdown of these materials is utilized in virtually all ecological processes that occur within the stream ecosystem. This degradation releases an enormous amount of usable energy, which may surpass the energy produced internally by photosynthesis (Allan, 1995).

This study focused on one such source of organic matter, summer leaf fall. Many studies in the past have involved leaves after, or near, abscission. However, significant amounts of leaves enter streams in the summer months, and such terrestrial inputs of summer leaves often constitute the energy base of small streams (Triska and Sedell, 1976).

In this study, the effects of varying nutrient levels, principally nitrogen and phosphorus, on the macroinvertebrate colonization and decomposition rate of alder leaves was studied in a northern Michigan stream. In a previous experiment in this same stream by Maloney and Lamberti (1994), alder leaves exhibited a decomposition rate $k = -0.077$ (day^{-1}) with 5% total leaf mass remaining after 42 days (when not supplemented with additional nutrients). In their study, net-spinning caddisflies and midge larvae dominated macroinvertebrate colonization of leaf packs.

While increased phosphorus has not been found to increase processing rates (Webster and Benfield, 1986), nitrogen enrichment has been found to increase degradation by 2.8 fold (Meyer and Johnson, 1983). This increased decomposition is likely a result of increased biofilm and microbial growth on nutrient-enhanced leaves, which also exhibit accumulation of nitrogen rich compounds (Meyer and Johnson, 1983). In addition to the microbes' ability to enhance decomposition directly.

substrates rich in biofilm and microbial growth are likely important food resources for grazing and shredding macroinvertebrates (Stout et al., 1985), which would also encourage rapid leaf degradation. My hypothesis was that increased nutrient supply would lead to greater numbers of macroinvertebrates colonizing the leaf packs and more rapid leaf decomposition.

METHODS AND MATERIALS

This study was conducted in Tenderfoot Creek, which is in the Upper Peninsula of Michigan at the University of Notre Dame Environmental Research Center (UNDERC). Fresh alder leaves were collected from the riparian zone of the stream. Healthy leaves were picked at similar distances from the ends of branches in order to minimize any potential influence of leaf age on decomposition (Stout et al., 1985). The leaves were then dried at 40 C for 24 hours.

The leaves were placed into mesh bags, which are commonly used for leaf decomposition studies (Meyer and Johnson, 1983; Stout et al., 1985; Maloney and Lamberti, 1994). After weighing, approximately 5g of leaves were wetted and enclosed in each of 60 bags. The leaf packs were individually coded so that the initial weight of each leaf pack was known. The packs were then attached to rocks. A 15 mL eppendorf tube was tethered to each pack. The eppendorf tubes were drilled with a small bit to make 20 holes for water and nutrient passage. Twenty of the tubes were left empty (control), 1 plant nutrient spike was placed in 20 tubes (low nutrient treatment), and the remaining 20 tubes contained 3 spikes (high nutrient treatment). Spikes contained a Nitrogen to Phosphorus to Potash ratio of 10:5:7.

All leaf packs were placed in Tenderfoot Creek, each oriented so that the brick's length was perpendicular to the current, with the eppendorf tube attached to the upstream portion of the leaf pack. The 20 control packs were placed furthest upstream to minimize nutrient exposure, and the high nutrient treatment packs were placed furthest downstream, leaving the low nutrient packs in the middle. All three rows were spread to span the entire channel width, and the packs were arranged in a staggered layout.

Every three days, 1 new spike was placed in the low nutrient packs, and 3 new spikes were placed in the high nutrient packs.

On days 2, 14, 28, and 42, packs were randomly selected from each of the three treatments. On days 2 and 14, five packs were selected from each treatment. Because of loss of leaf packs, four packs were selected from each treatment on days 28 and 42. The leaves were oven-dried at 40 C for 24 hours and weighed according to Maloney and Lamberti (1994). On days 14 and 42, macroinvertebrates were washed from the leaves into a 250 micrometer sieve and stored in 80% ethanol. Macroinvertebrates were counted and identified to genus except for Chironomidae, which were identified to family.

Leaf processing rates were calculated according to the formula:

$$W_t = W_i e^{-kt}$$

Where:

W_t = dry mass at time t

W_i = initial dry mass

t = # of days

k = processing rate (days^{-1}), is equal to the slope of the plot of \log_e of leaf mass versus time.

RESULTS

ANOVA analysis revealed that the processing rate (k) of each treatment differed significantly ($P < 0.001$). Over the 42 day period, control packs had a processing rate of 0.0435 day^{-1} , low treatments had a rate of 0.0492 day^{-1} , and high nutrient treatments had a processing rate of 0.0427 day^{-1} , respectively (fig. 1).

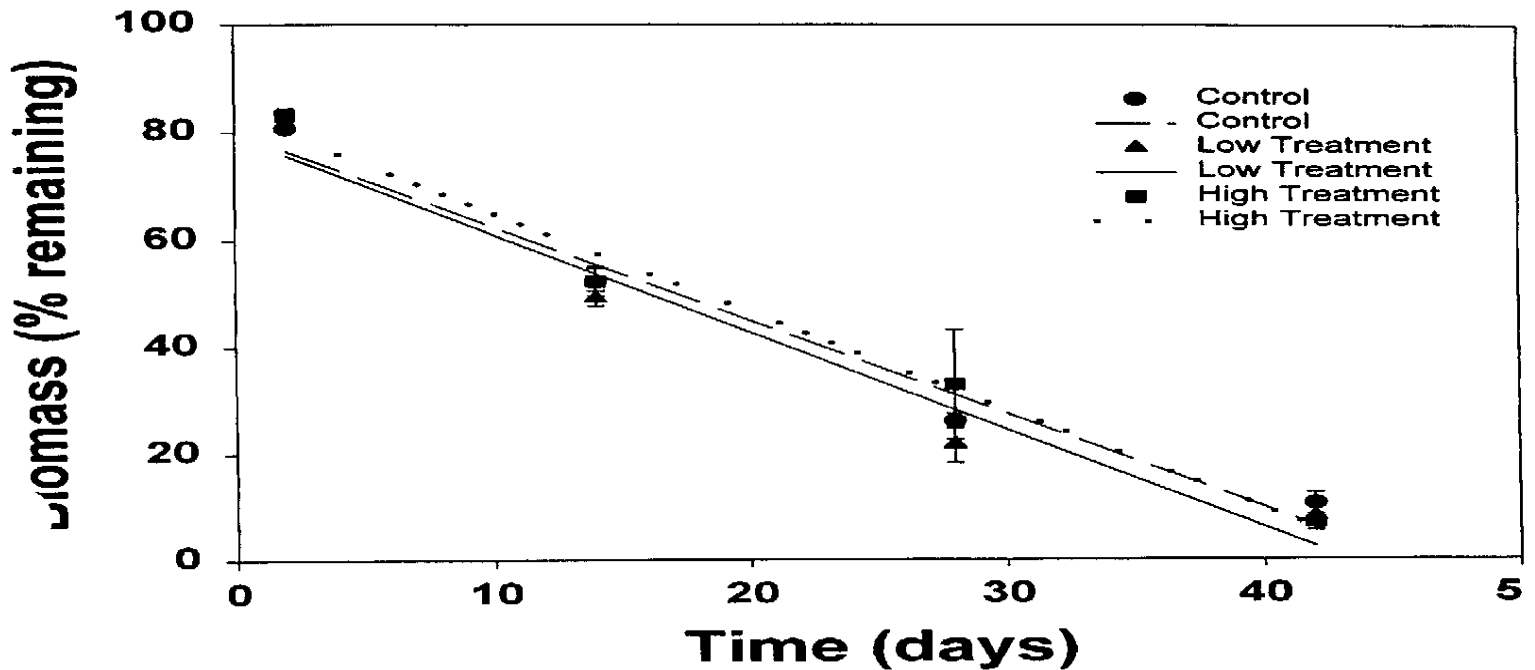


Figure 1. Decomposition of alder leaves in the three nutrient treatments over 42 days.

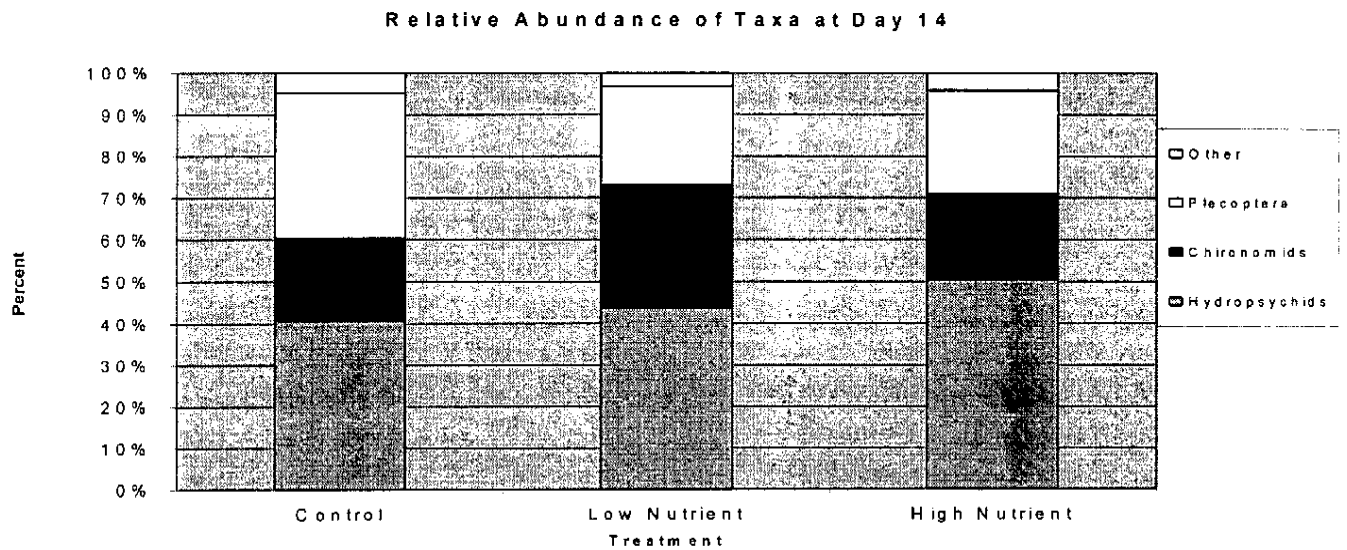
The numbers of macroinvertebrates per leaf pack for all three treatments were greater on day 14 than day 42. On day 14, the high nutrient packs contained the largest number of macroinvertebrates, whereas the low nutrient treatment packs had the largest numbers on day 42 (Table 1).

Table 1. Taxa and average number of macroinvertebrates per leaf pack in all treatments on days 14 and 42.

Taxon	14 Day Control	42 Day Control	14 Day Low	42 Day Low	14 Day High	42 Day High
Plecoptera						
Perlidae						
<i>Perlsta</i>	41	0.8	32.8	2.5	36.4	1.3
Trichoptera						
Hydropsychidae						
<i>Hydropsyche</i>	15	17.5	19.8	32.8	23.8	26.8
<i>Cheumatopsyche</i>	28.8	21.25	37.2	21.3	44.6	25.5
<i>Potamyia</i>	3.4	0	3.4	0	5	0
<i>Parapsyche</i>	0.6	0	0	0	0	0
<i>Ceratopsyche</i>	0	0	0.2	0	0	0
<i>Diplectrona</i>	0	0	0	0	0	0
Polycentropodidae						
<i>Polycentropus</i>	0.4	0	0	0		0
Leptoceridae					0	
<i>Triaenodes</i>	0.6	0	0	0	0	0
Limnephilidae						
<i>Hesperophylax</i>	0.2	0	0	0.2	1	0
<i>Hydatophylax</i>	0	0.2	0	0		0
Brachycentridae						
<i>Brachycentrus</i>	0.6	0	0.8	0	1	0
Philopotamidae						
<i>Wormaldia</i>	0	0.4	0	0	0	0
Phryganeidae						
<i>Phryganea</i>	0	0	0	0	0.2	0
Diptera						
Chironomidae	23.2	9.5	40.8	29	30	21.8
Ceratopogonidae						
<i>Bezzia</i>	0.4	0	1.2	0.2	0.6	0
Coleoptera						
Elmidae						
<i>Stenelmis</i>	0.2	0.4	0	0	0.2	0
<i>Optioservus</i>	0.2	0	0	0	0	0
Ephemeroptera						
Ephemerellidae						
<i>Ephemerella</i>	0.8	1.8	0	4	0	1.3
<i>Serratella</i>	2.2	5.5	0	9.8	0	3
Heptageniidae						
<i>Macdunnoa</i>	0	0	0.6	0	0	0
Baetidae						
<i>Baetis</i>	0	2	1.6	0	2.6	0
Odonata						
Gomphidae						
<i>Ophiogomphus</i>	0	0	0.2	0.2	0	0
Megaloptera						
Corydalidae						
<i>Nigronia</i>	0	0	0	0	0.4	0
TOTALS	117.6	59.4	138.6	100	145.8	77

All leaf packs contained mostly Hydropsychid caddisflies and Chironomid midges on both sampling days. The three treatments contained significant numbers of Plecoptera on day 14, but by day 42 Plecoptera represented only a minor fraction of total invertebrate numbers (Fig.2).

A.



B.

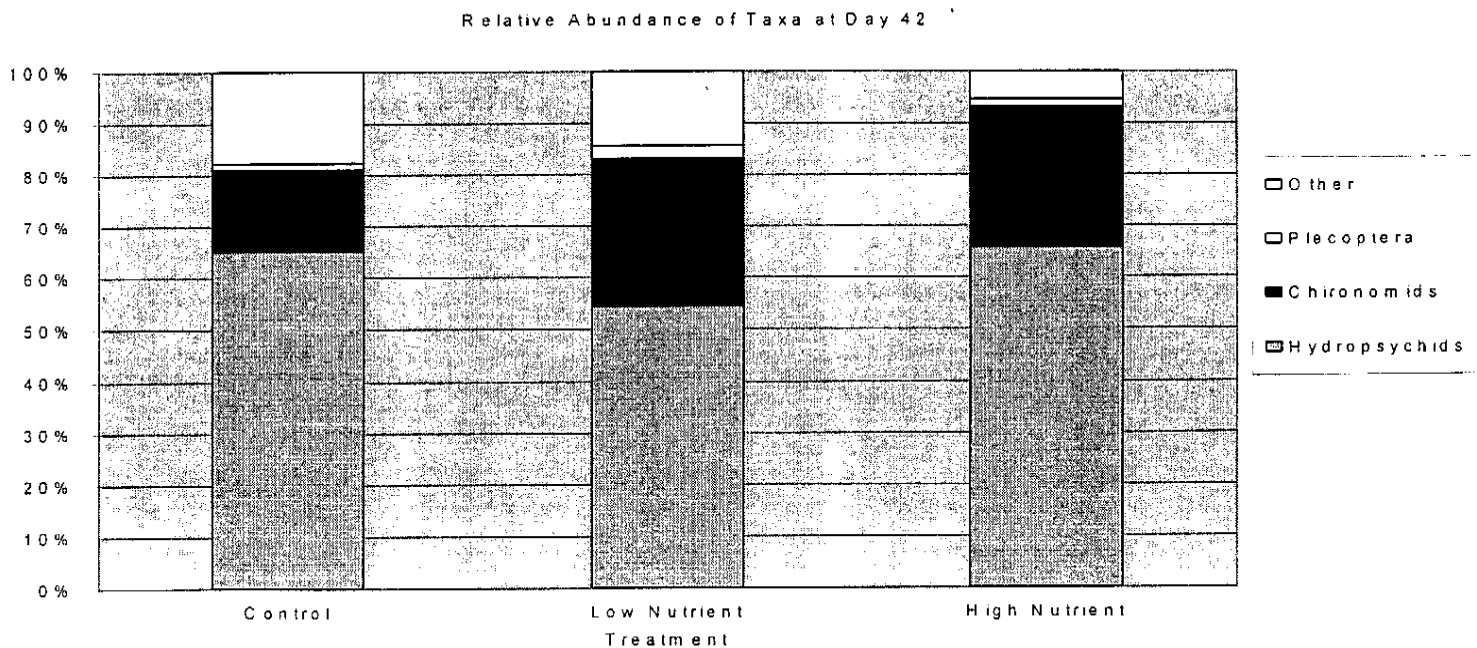
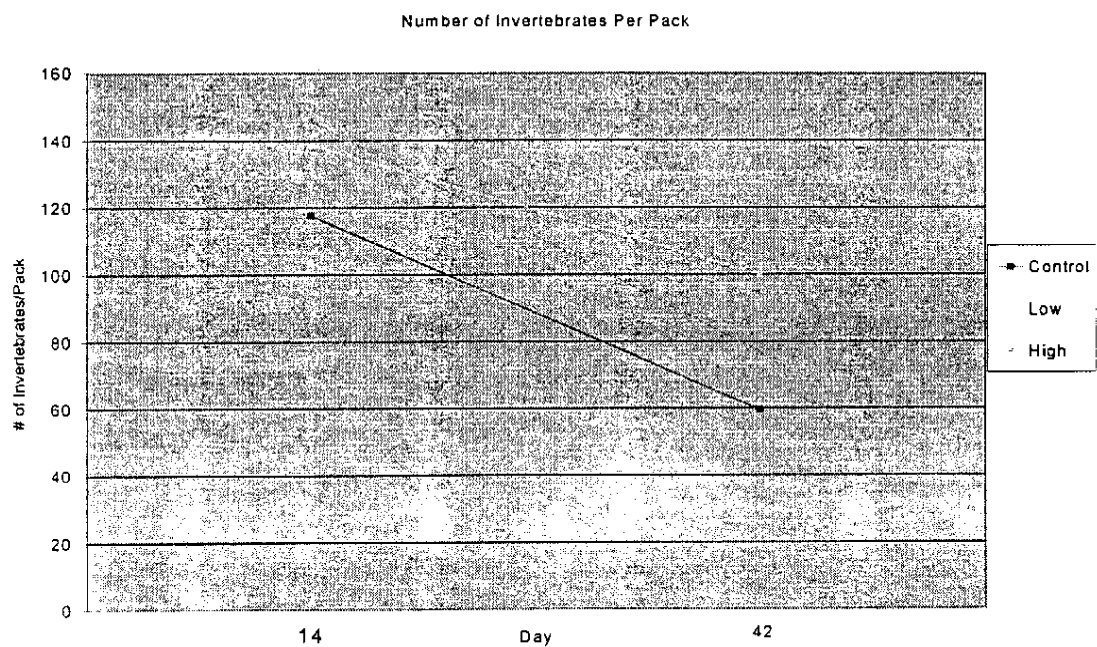


Figure 2. Relative abundance of macroinvertebrate taxa in leaf packs on A) day 14 and B) day 42.

The number of macroinvertebrates per leaf pack declined from days 14-42 (Fig 3A). However, the number of macroinvertebrates per gram of dry leaf mass increased over time for all three nutrient conditions. On both sampling days, the high nutrient packs had the fewest macroinvertebrates per unit of leaf mass, whereas the low nutrient packs had the highest number of macroinvertebrates per gram. (Fig. 3B).

A.



B.

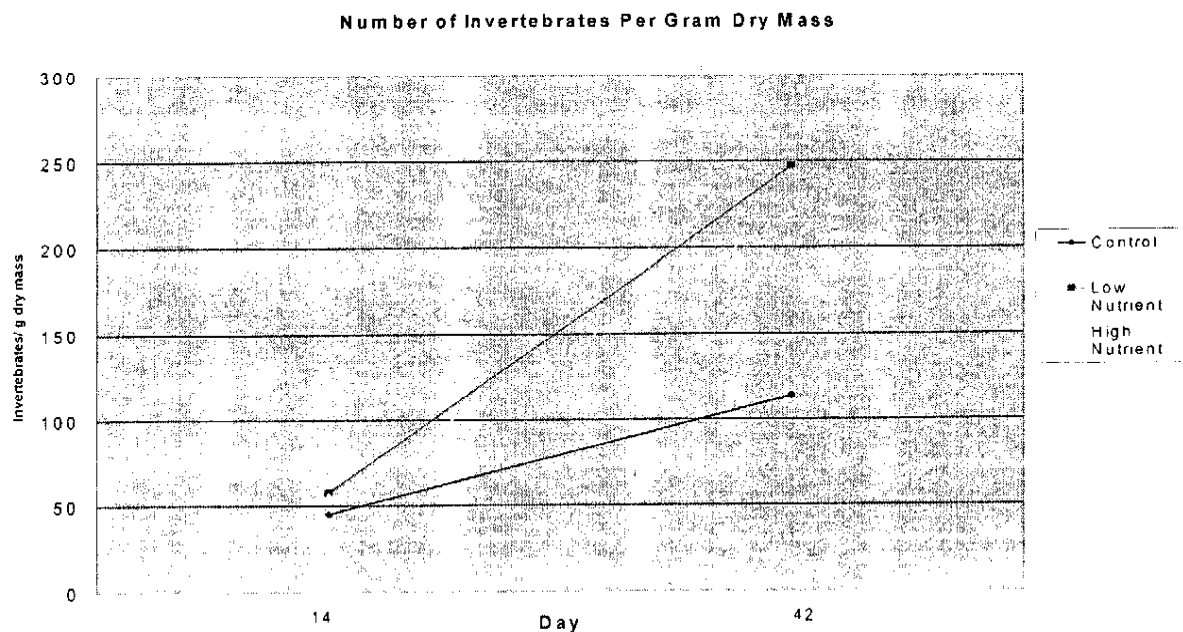
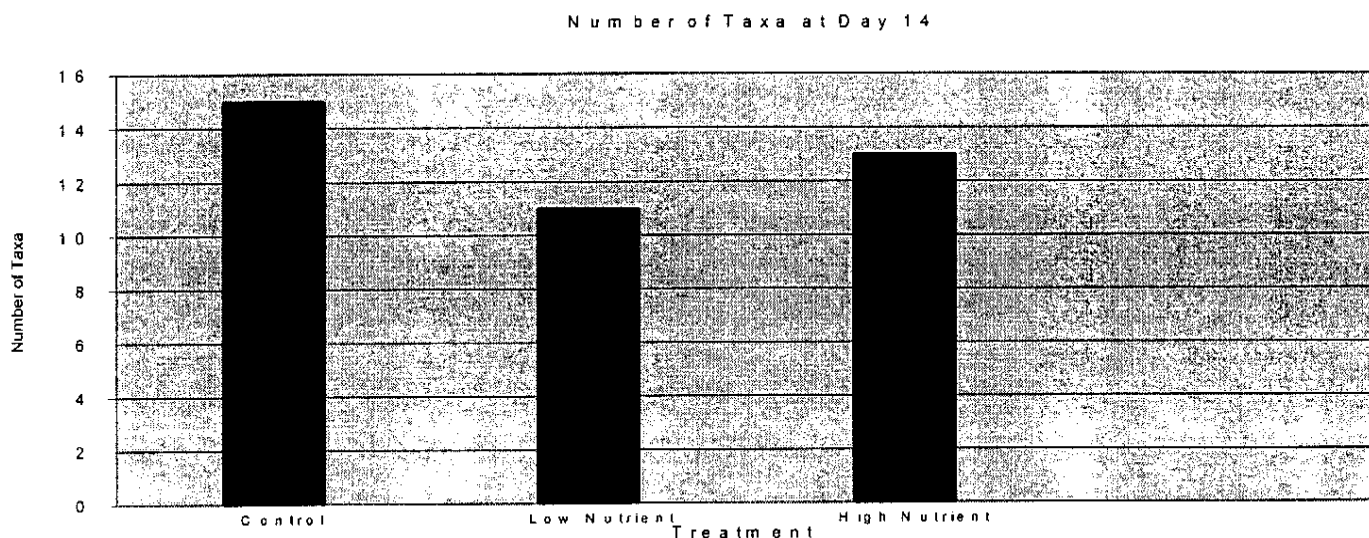


Figure 3. A) Average Number of macroinvertebrates per leaf pack. B) Number of Macroinvertebrates per gram of dry leaf material.

Not only did the number of macroinvertebrates decline over the sampling period, but the number of taxa present in the packs declined as well. All three treatments had a larger number of taxa on day 14 than on day 42. The control packs possessed the highest number of taxa on days 14 and 42 and the high nutrient packs showed the largest decline in taxa over the experiment (fig. 4).

A.



B.

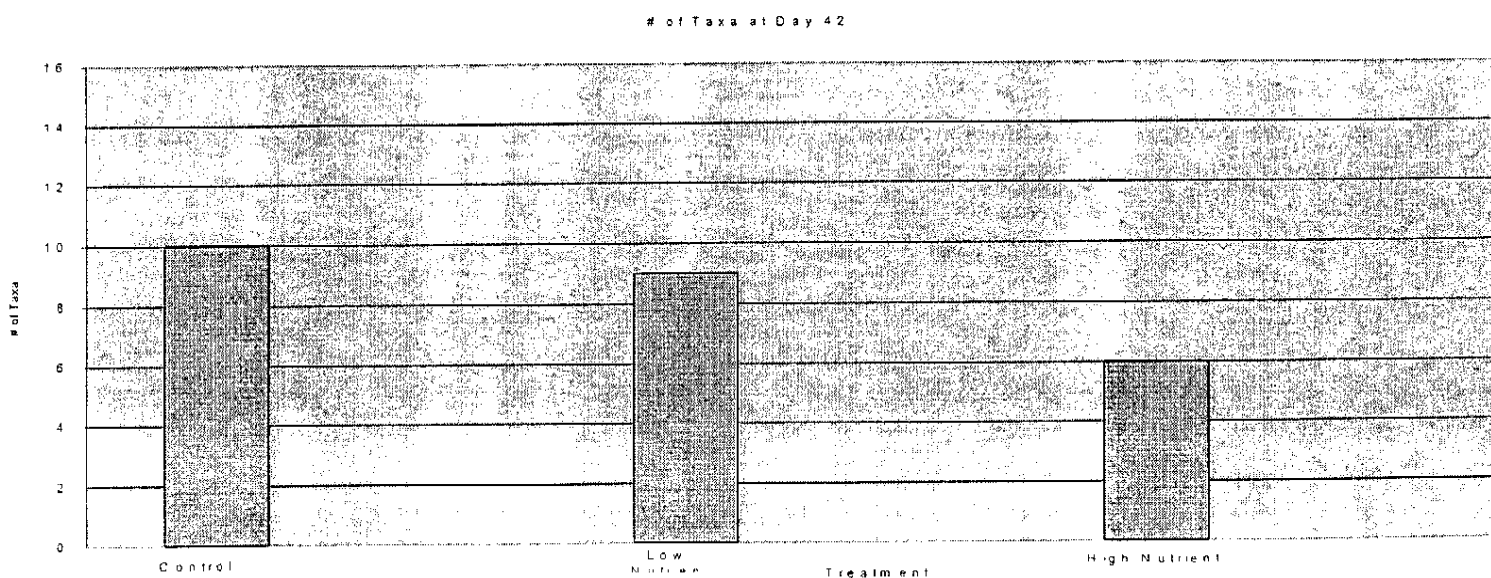


Figure 4. Number of different taxa present in leaf packs on day A) 14 and B) 42.

DISCUSSION

In this study, decomposition rates (0.0427 - 0.0492 day^{-1}) for speckled alder were lower than the rate found for alder ($k= 0.077$) in a previous experiment in the same stream (Maloney and Lamberti, 1994). However, Stout et al. (1985) recorded processing rates of $k=0.0171$ and $k=0.0126$ for summer-picked speckled alder leaves in two Michigan streams, which were substantially lower than either this study or the study by Maloney and Lamberti (1994).

Although the processing rates of the different treatments in this study were similar, the low nutrient treatment had a significantly faster decomposition coefficient than the other two treatments, while high nutrient packs decayed the slowest. Thus, it appears that, while some nutrient enrichment increased decomposition, at a certain point the increased nutrient load became inhibitory. This apparent inhibition may result from the increased biofilm growth on high nutrient leaf packs. Substantial biofilm cover could allow macroinvertebrates, many of which are omnivores, to primarily feed on biofilm instead of leaf material, which would slow leaf processing. Low nutrient packs likely had increased growth, but not enough to serve as the main source of food for macroinvertebrates.

Over time, macroinvertebrate numbers decreased, likely a result of the decreased amount or nutritional quality of the leaves as they were processed. By the end of the study, the leaf material was composed mostly of petioles and veination. These structures are highly lignified, which has been found to resist decomposition (Aerts, 1997). This decline in macroinvertebrate number may also result from the life

cycles of the organisms found in the packs. As the season progressed, many of the larvae may have simply matured into their terrestrial adult forms and left the packs.

When compared to the previous work by Maloney and Lamberti (1994), this study resulted in much lower numbers of macroinvertebrates colonizing the leaf packs. While the preceding study resulted in macroinvertebrate numbers in excess of 800 per pack on day 14 and nearly 700 per pack on day 42, numbers from day 14 of this study ranged from 118-146 per pack and 59 –100 on day 42. This difference may be related to the packs' exact location within the stream, from differences in leaf pack construction, or from the arrangement of leaves within the packs. Finally, yearly difference in the abundance of the total macroinvertebrate community could account for some of the drastic disparity in macroinvertebrate colonization in the two studies.

Leaf packs contained few macroinvertebrates classified as shredders and rather were dominated by collectors. However, both hydropsychid and chironomid larvae are often omnivorous (Hilsenhoff, 1995). Thus, it is possible that they fed mostly on leaf material in the initial days of the study, but as the leaves decomposed and the nutritive of the leaves decreased, such omnivores spent more time grazing and filter feeding.

A striking result of this study is the sharp decline in the number of Plecoptera between days 14 and 42. On day 14, Plecoptera accounted for 27% of taxa colonizing all leaf packs, but made up only 2% of organisms in the packs on day 42. This decline in stoneflies is likely due to large numbers of the Plecoptera maturing into adults and leaving the aquatic environment. This assumption is supported by the finding of multiple adult stoneflies that had apparently emerged within the leaf packs between the time they were pulled from the water and the time when the packs were opened and macroinvertebrates were removed. This decrease in the number of Plecoptera, which are predators, may be partly responsible for the increase in the number of *Hydronycha*

caddisflies from day 14 to 42 and in the relative abundance of Hydropsychids on the last sampling date.

Throughout the experiment, the low nutrient treatment possessed the largest number of invertebrates per gram of dry leaf mass, which has been linked to faster processing (Meyer and Johnson, 1983). Low nutrient packs, although never the richest in the number of taxa colonizing them, experienced the least decline in taxa richness between sampling days. This may signify the low nutrient packs' ability to support a stable and productive macroinvertebrate community that was able to sustain itself effectively even in the absence of abundant nutritious leaf material. Conversely, high nutrient packs, which showed the slowest processing rates, experienced the steepest drop in species richness. This may represent a much more transient and unproductive community which was unsuccessful at both sustaining itself and rapidly decomposing the alder leaves in the packs. The decline in taxa richness seen in this study has been found in other studies involving alder leaves (Stout et al., 1985).

Low levels of additional nutrients, mainly nitrogen and phosphorus, accelerated leaf processing rates. However, when high levels of nutrients were added to leaf packs, processing rates were lower than in control packs. Further studies into this possible inhibitory effect of high nutrient levels should include analyses of nutrient concentrations. The mass and nutrient content of the biofilm on leaves should also be considered. Because Meyer and Johnson (1983) found that shredding macroinvertebrates in plant litter enriched with nitrogen were larger and shorter lived than normal, this relationship should be examined in future studies as well.

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LITERATURE CITED

- Allan, J. David. (1995) **Stream Ecology** Structure and Function of Running Waters. Chapman and Hall, London.
- Hilsenhoff, William L. (1995) **Aquatic Insects of Wisconsin**. Natural History Museums Council, University of Wisconsin.
- Maloney, Daniel C., and Lamberti, Gary A. (1994) Rapid Decomposition of Summer-Input Leaves in a Northern Michigan Stream. *Am. Midl. Nat.* 133, 184-95.
- Meyer, J.L. and Johnson, C. (1983) The Influence of Elevated Nitrate Concentration On Rate of Leaf Decomposition in a Stream. *Freshwater Biol.*, 13, 177-83.
- Stout, R.J., Taft, W.H., Merritt, R.W. (1985) Patterns of Macroinvertebrate Colonization On Fresh and Senescent Alder Leaves in Two Michigan Streams. *Freshwater Biol.*, 15, 573-80.
- Triska, F.J. and Sedell, J.R. (1976) Decomposition of Four Species of Leaf Litter in Response to Nitrate Manipulation. *Ecology.* 57, 783-792.
- Webster, J.R. and Benfield, E.F. (1986) Vasculature Plant Breakdown in Freshwater Ecosystems. *Annu. Rev. Ecol. System*, 17, 567-94.