LEAF LITTER DECOMPOSITION AND ELEMENTAL CHANGE IN THREE APPALACHIAN MOUNTAIN STREAMS OF DIFFERENT PH

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Abstract: The decomposition of leaf litter provides the primary nutrient source for many of the headwater mountain streams in forested catchments. An investigation of factors affected by global change that influence organic matter decomposition, such as temperature and pH, is important in understanding the dynamics of these systems. We conducted a study of leaf litter elemental change during decomposition in three headwater mountain streams within or near the Fernow Experimental Forest, Monongahela National Forest, West Virginia. Three leaf species, placed in individual leaf bags, were placed in three streams that had mean pH values of 4.2, 6.2, and 7.5. Nitrogen, expressed as percent of initial concentration, was conserved in leaf litter in all three streams. Nitrogen concentrations were not significantly different in the acidic stream as compared with the more neutral streams. In contrast, phosphorus was lost more rapidly from the leaf detritus in the acidic stream (45.9 percent), than in the more neutral streams (52.0 percent and 63.1 percent). The rates of decomposition for white oak and red maple were significantly lower (k = 0.0062 for red maple) in the acidic stream as compared with the more neutral streams, WSH and HSH (k = 0.0128 and 0.0072, respectively). Although no differences in final nitrogen content were observed, detrital decomposition, microbial biomass, and the accumulation of phosphorus, calcium, and magnesium were inhibited in the low pH stream. These results suggest that acidification may significantly reduce the rate of leaf detrital breakdown, which may result in a reduction of the nutrient base for aquatic consumers.

INTRODUCTION

The trophic structure and secondary production in stream ecosystems is controlled by both the quality and quantity of leaf litter. Decomposition is often the major source of nutrients to both microconsumers and macroconsumers in headwater streams. Mobilization of nutrients from leaf detritus during decomposition is regulated by environmental factors such as stream water chemistry, temperature, and stream biota, as well as by the physical and chemical composition of the detrital substrate (Gosz et al., 1973; Melillo et al., 1984; Rustad, 1994).

Changes in precipitation chemistry may affect detrital-based ecosystems that are otherwise unaffected by land use in a watershed. Acidification of streams as a result of atmospheric inputs may introduce changes in water chemistry, particularly depression of pH. These changes in water chemistry may, in turn affect detrital decomposition and the associated biogeochemical processes that influence every trophic level (Haines, 1981).

The goal of our research was to compare detrital processing rates and temporal changes in detrital nutrients among streams with different pH. We measured changes in mass loss rates, microbial biomass, and elemental composition of leaf litter to provide insight into the effects of stream acidification on detrital processing and detrital quality.

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STUDY SITES

This study was conducted in three streams within or near the Fernow Experimental Forest, Monongahela National Forest, West Virginia. The study sites are within the physiographic region of the central Appalachian Mountains known as the Allegheny Plateau. Headwater streams of this region tend to form dendritic stream patterns common in landscapes originating from an elevated plateau that was previously level.

The South Fork of Red Run (SFR) is a second-order stream (mean pH = 4.2) draining approximately 230 hectares underlain by silicate sandstones and conglomerate of the Pottsville formation. The riparian forest is dominated by red maple (*Acer rubrum* L.), yellow poplar (*Liriodendron tulipifera*), eastern hemlock (*Tsuga canadensis* L.), and rhododendron (*Rhododendron maximus* L.).

Wilson Hollow (WH) is a third-order stream (mean pH = 6.2) which drains approximately 128 hectares underlain by shales and siltstones of the Hampshire formation. The riparian forest consists of red oak (*Quercus rubra* Michx.), eastern hemlock (*Tsuga canadensis*), and sugar maple (*Acer saccharum*).

The North Fork of Hickman Slide Hollow (HSH), also in the Fernow Experimental Forest, is a second-order stream (mean pH = 7.5) draining a 72 hectare catchment underlain by the Mauch Chunk formation. The Mauch Chunk consists of shales and sandstones, as well as heavily jointed limestones of the Greenbriar member. The riparian vegetation is similar to that of Wilson Hollow.

METHODS

Three leaf species, white oak (*Quercus alba*), red maple (*Acer rubrum*), and yellow poplar (*Liriodendron tulipifera*) were selected. These species represent leaves that decompose at relatively slow, medium, and fast rates, respectively. Thirty-five leaf packs of each leaf species were placed in each of the three streams in November 1992. Five leaf packs of each species were retrieved from each stream after two days, two weeks, four weeks, and then at four-week intervals until March 1993. To measure the ash-free dry weight (AFDW), random subsamples of ten leaf disks were taken from the rinsed leaf pack material using a 1 cm diameter cork borer. Remaining leaf pack dry weight was then multiplied by the percent AFDW to estimate the remaining leaf pack AFDW. Microbial biomass estimations were made using ATP extraction and analysis with luciferin-luciferase enzyme system (Suberkropp et al. 1976).

A random experimental design was employed to examine the effects of stream, leaf species, and the interaction on rates of decomposition and elemental change. Both stream and leaf species were considered fixed effects. Differences in mean nutrient content after 112 days of incubation were evaluated using analysis of variance (ANOVA). Because sample sizes were unequal for some of the parameters that were measured, the general linear models and least-squares means procedures were used. Analysis of covariance was used to compare changes in mass loss among streams.

RESULTS

In terms of mass loss of the detritus, the rates of decomposition were significantly lower ($k = 0.0062$, for red maple) in the acidic stream, SFR, as compared with the more neutral streams, WH and HSH ($k = 0.0128$ and 0.0072, respectively). This trend was also observed in white oak but not in yellow poplar.

Following a decline in nitrogen concentration during the first 20 days, nitrogen was conserved in all three leaf species. No significant difference in final nitrogen content of the detritus was observed among the three streams. Similarly, phosphorus and calcium were conserved in detritus from the two neutral streams, but were lost from detritus in the acidic stream. The final content of phosphorus was significantly lower in the acid stream SFR (45.9 percent for red maple), than in either of the two neutral streams WSH (52.0 percent) and HSH (63.1 percent), which were not significantly different from each other. Calcium in detritus was also conserved, but only during the first 20 days in the alkaline stream, HSH. Calcium was lost by detritus by both SFR and WH.

Magnesium was lost by the detritus in all three species. Magnesium in SFR was significantly lower (4.09 percent for red maple) than WH and HSH, 25.3 percent and 25.7 percent respectively, which were not significantly different. Potassium was rapidly leached from detritus in all three streams.

Microbial biomass on the detritus was significantly lower in the acidic stream, SFR (38.2 ng ATP/g for red maple), in comparison with the more neutral streams, WH (201.5 ng ATP/g) and HSH (145.2 ng ATP/g).

DISCUSSION

We concluded that litter decomposition and elemental accumulation or loss in aquatic detrital material was strongly influenced by water chemistry. Of the water quality variables measured, pH appeared to be the most important in determining decomposition rates. Decomposition rates and microbial colonization are significantly reduced in acidic conditions.

Nitrogen was conserved in the detrital material over time. However, no significant differences in net nitrogen concentration were observed among the three streams. This suggests that decomposition is not controlled by nitrogen alone in our study streams. Nitrogen conservation was most likely the result of loss of more labile leaf litter components such as potassium.

Phosphorus was conserved in the two neutral streams but was lost in the acidic stream. Phosphorus may be accumulating on detritus in the two neutral streams as a result of contributions of phosphorus by the microbial community. Mulholland et al. (1984) suggested that phosphorus accumulation in decomposing leaf detritus is a function of microbial biomass and activity within the detritus. Phosphorus loss in the acidic stream may be the result of the reduced microbial biomass.

Elemental changes in calcium and magnesium may be the result of the location of these components within the detritus or the presence of refractory materials. Potassium, the most mobile element measured, was rapidly leached from the detritus.

Our results indicate that, with the exception of nitrogen, detrital elements are lost more rapidly in the acidic stream than in the more neutral streams. In addition, both decomposition rate and microbial biomass were also lower in the acidic stream. This suggests that elemental content of detritus was more rapidly depleted under acidic conditions, reducing quality for macroconsumers. In addition, lower microbial biomass in detritus in acidic systems may result in slower conditioning rates which may also contribute to lower detrital quality, an important factor in detrital-macroconsumer relationships.

LITERATURE CITED

Gosz, J. R., Likens, G. E., and Bormann, F. H. 1973. Nutrient release from decomposing leaf and branch litter in the Hubbard Brook Forest, New Hampshire. Ecological Monographs 43:173-191.

Haines, T. A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110:669-707.

Melillo, J. M., R. J. Naiman, J. D. Aber, and A. E. Likens. 1984. Factors controlling mass loss and nitrogen dynamics of plant litter decaying in northern streams. Bulletin of Marine Sciences 35:341-356.

Mulholland, P. J., Elwood, J. W., Newbold, J. D., Webster, J. R., Ferren, L. A., and Perkins, R. E. 1984. Phosphorus uptake by decomposing leaf detritus: effect of microbial biomass and activity. Verhandlungender Internationalen Vereinigung fuer Theoretische und Angewandte Limnologie 22:1899-1905.

Rustad, L. E. 1994. Element dynamics along a decay continuum in red spruce ecosystem in Maine, USA. Ecology 75:867-879.

Suberkropp, K., Godshalk, G. L., and Klug, M. J. 1976. Changes in the chemical composition of leaves during processing in a woodland stream. Ecology 57:720-727.