LEAF LITTER PROCESSING IN WEST VIRGINIA MOUNTAIN STREAMS: EFFECTS OF TEMPERATURE AND STREAM CHEMISTRY

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Abstract: Climate change has the potential to alter detrital processing in headwater streams, which receive the majority of their nutrient input as terrestrial leaf litter. Early placement of experimental leaf packs in streams, one month prior to most abscission, was used as an experimental manipulation to increase stream temperature during leaf pack breakdown. We studied leaf litter processing in three second-order, mid-Appalachian streams along a pH gradient (mean pH = 4.2, 6.5, 7.5). Leaf pack processing rate coefficients (k) were calculated for single species leaf packs of red maple, white oak, and yellow poplar retrieved from each stream at regular intervals over two 12-week study periods: October to January, average total degree days = 442.0; and November to February, average total degree days = 271.3. Processing rates for all leaf species in both study periods were highest in the most alkaline stream. Within each stream, processing rates were not significantly higher during either study period. Invertebrate density was higher during the earlier, warmer study period, but shredder biomass showed no significant trends. ATP concentrations on leaf material were generally higher during the earlier study period, indicating higher microbial biomass. Overall, leaf litter processing in this study was influenced by a combination of factors including temperature, water chemistry, invertebrate community, and microbial processing.

INTRODUCTION

Potential global climate change over the next century may alter regional climate and precipitation patterns (Levine 1991). The probable effects of climate change on stream ecosystems include altered flow and temperature, which in turn can affect ecosystem energy flow, individual species distributions, and interspecific interactions (Carpenter *et al.* 1992). Forested headwater streams receive the majority of their nutrient input in the form of terrestrial leaf litter (Fisher and Likens 1973, Vannote *et al.* 1980). By altering the temperature and flow regimes of these forested headwater streams, climate change may affect rates of leaf litter breakdown in streams and also the life histories of stream-dwelling invertebrates that consume leaf litter, known as shredders.

Typically, researchers have studied detrital processing in streams by placing small packs of leaves in streams to coincide with the timing of maximum natural leaf input (e.g., Petersen and Cummins 1974, Benfield and Webster 1985, Griffith and Perry 1993). We used early placement of leaf packs in streams, one month prior to most abscission, in this study to increase the accumulation of degree-days over the processing period. This was done in order to investigate the role of increased temperature during leaf pack breakdown.

STUDY SITES

This study was conducted from October 1993 to February 1994 in three second-order streams of different pH: South Fork of Red Run (SFR, mean pH = 4.2), Freeland Run (FR, pH = 6.5), and Hickman Slide Hollow (HSH, pH = 7.5).

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The streams are located in (HSH) or near (SFR, FR) the Fernow Experimental Forest, Monongahela National Forest, Tucker County, WV.

METHODS

Water temperature was recorded by continuous recording thermographs in each stream. Water quality variables, including pH and total aluminum, were measured from grab samples analyzed by the USFS Timber and Watershed Lab, Parsons WV, and PKC Environmental, Morgantown, WV. Single species leaf packs (red maple, white oak, yellow poplar) were constructed by placing 10 g of dried abscised leaves in mesh bags, which were then attached to bricks and placed in the streams. Five packs of each species were removed from each stream at predetermined intervals: approximately two days, two weeks, four weeks, eight weeks, and 12 weeks after the packs were originally placed in the stream. Early leaf packs were in place from October to January, and normal leaf packs were in place from November to February.

In the laboratory, ash free dry weight remaining was determined. Invertebrates were separated from the leaf matter, preserved, and later identified, counted, and weighed to determine invertebrate biomass. Microbial biomass was estimated by determining ATP concentration on leaf discs cut from the leaf packs, using acid-extraction techniques (Suberkropp and Klug 1976). Rates of leaf pack decomposition were calculated as the rate coefficient (k) of a negative exponential model of leaf pack decay (Petersen and Cummins 1974). Separate calculations of k were made using either days or degree days as the independent variable, in an attempt to account for temperature differences between the two sampling periods (Griffith and Perry 1993, Irons *et al.* 1994). Degree days accumulated at each sample date were calculated as the cumulative sum of the mean daily temperatures from the beginning of the study to that sample date. The General Linear Models (GLM) procedure of SAS was used to contrast decay rate coefficients between the study periods and streams. Invertebrate shredder density and biomass and ATP concentrations were also compared between study periods and streams using the GLM procedure and Duncan's Multiple Range Test as a multiple comparison procedure, with $\alpha = 0.05$.

RESULTS

Degree-day accumulation during the early study period was highest in HSH, the lowest elevation stream (533 degree days), intermediate in SFR (410), and lowest in FR (384). Over the normally timed experiments, the three streams accumulated 367 degree days (HSH), 234 degree days (SFR), and 213 degree days (FR).

Mass loss rate coefficients are reported in two ways: from the regression of time in days versus ln AFDW remaining (k), and from the regression of degree-days versus ln AFDW remaining (k_d). Values of k were highest in HSH, intermediate in FR, and lowest in SFR, and also varied by leaf species. In general, yellow poplar leaves broke down the fastest, red maple leaves broke down at an intermediate rate, and white oak leaves broke down the slowest. No significant differences were seen when k was contrasted between early and normally-timed experiments within the same stream.

Values of k_d were calculated as a means of incorporating variation in temperature into the leaf litter breakdown rate. Values of k_d were highest in FR or HSH, and lower in SFR. These rate coefficients (k_d) were significantly higher during the normally-timed experiments in HSH for all leaf species, and in FR for oak leaves.

Invertebrate density differed among the three study streams. Density was generally highest in either SFR or FR, and lower in HSH, for both study periods. Density was significantly higher in the early study period for all leaf species in HSR and FR. In SFR, densities were higher during the normal study period for red maple and white oak leaf packs. Invertebrate biomass also differed among the three streams. Biomass was highest in FR, intermediate in HSH, and lowest in SFR. This indicates that the shredder community in SFR was composed of many small individuals. Shredder biomass was higher during the normal study period, particularly on the last two sample dates. However, no statistically significant differences in biomass could be detected between study periods when considering all sample dates of both studies.

ATP concentrations, approximations of microbial biomass on leaf material, were significantly higher in the early study period for red maple and yellow poplar leaves. ATP concentrations were generally higher in FR and HSH, and low in SFR.

DISCUSSION

Stream temperature has a recognized role in leaf litter breakdown and related stream processes such as invertebrate and microbial metabolism. Processing rates have been shown by some researchers to increase directly with temperature; yet in this study, the warmer study period generally had similar or even slower breakdown rates. In other studies that compared processing in streams with different temperature regimes, faster processing rates in cooler streams have often been attributed to more abundant shredders in the cooler streams (Triska and Sedell 1975, Short *et al.* 1980). However, still other studies comparing processing rates in the same stream during different study periods have found no significant differences in breakdown rate between study periods (Petersen and Cummins 1974), as was the case in the present study.

The differences in processing rates between early and normal study periods seen with the inclusion of degree-days in the breakdown rate calculation may indicate that temperature is a factor. Still, this method of rate calculation may not fully account for temperature differences between streams and study periods. The temperature differences in our two study periods may have been too slight to produce the expected effect of higher rates at higher temperatures, since temperature effects appear to have been confounded by other factors, particularly the biomass and life histories of shredding invertebrates.

Major effects of climate change on organic matter processing in streams may result over much longer time scales, as the range of tree species, timing of leaf abscission, and invertebrate life histories are affected. Future work may be directed toward exploring the impact of yearly variation in various climatic factors on leaf litter processing and the overall energy budget of streams in forested ecosystems.

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