BREAKDOWN RATES OF TULIP-POPLAR LEAVES IN STREAMS DRAINING SUBURBAN WATERSHEDS

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Abstract. Leaf litter inputs are an integral part of stream food webs. Changes to this basic food resource from natural or anthropogenic causes can have repercussions at higher trophic levels. Stormwater runoff from residential lawns transports pesticides and fertilizers to stream ecosystems. This study measures leaf breakdown rates in two suburban streams in Peachtree City, Georgia, and considers if fungicide or nutrient concentrations have impacted those rates. Leaf breakdown rates in these suburban streams were compared with breakdown rates in two reference streams. We analyzed stream temperature and concentrations of ammonium, nitrate, soluble reactive phosphorus, and selected pesticides. Relationships between these parameters and breakdown rates of tulip-poplar leaves (*Liriodendron tulipifera* L.) were examined. Surprisingly, nitrate, ammonium and hydroxychlorothalonil (a fungicide degradation product) concentrations were somewhat higher in the reference streams. Leaf breakdown rates for the first seven weeks were similar in three streams and lower in one of the reference streams. Differences in nutrient and pesticide concentrations were not consistent and could not explain observed differences in leaf breakdown rates.

INTRODUCTION

The importance of leaf litter as a food resource in streams is well documented (Allan 1995). It is a basic part of the food web and plays a significant role in heterotrophic streams as autumn-shed leaves are leached, decomposed by microbes, and consumed as a food resource by macroinvertebrates. Leaf breakdown occurs in three phases: initial rapid loss due to leaching, a period of microbial decomposition and conditioning, and mechanical and invertebrate fragmentation (Webster and Benfield, 1986). Microbes render a leaf more fragile while current velocity and macroinvertebrates break leaves into smaller parts. Tulip-poplar (*Liriodendron tulipifera*) leaves are a fast decay species with a reported decay coefficient of >0.010/day (Webster and Benfield, 1986).

In streams draining suburban watersheds, retention of leaves is decreased due to flashy flows, and increased peak flows. In addition, burial of leaf packs by sediment deposition can lead to a lower breakdown rate (Meyer, 1980). Buried packs are protected from turbulence and therefore are less subject to being broken up into smaller pieces by physical abrasion. Burial can also result in exposure to anaerobic conditions. Other variables, such as temperature, current velocity, nutrients, and leaf species also affect leaf breakdown rates (Webster and Benfield, 1986). Fertilizers could stimulate leaf breakdown by increasing nutrient availability, while pesticides likely inhibit the breakdown of leaves by killing fungi and leaf shredding benthic macroinvertebrates (Paul, 1999).

The four streams sampled in this study are located in Peachtree City, just south of Atlanta, Georgia, in the piedmont physiographic province. The study streams, Oak Creek and Smoke Rise Creek, drain primarily suburban neighborhoods, while the reference streams, Keg Creek and Crabapple Creek, drain mixed-use watersheds of forests and pastures with fewer residential developments. The reference streams were chosen to represent land use conditions occurring in this area prior to suburban development. The objective of this study was to compare leaf breakdown rates between study and reference streams and examine possible relationships between breakdown rates and pesticide and nutrient concentrations.

METHODS

Tulip-poplar leaves were collected as they fell from trees during autumn. Fifty air-dried, 8 gram leaf packs in coarse-mesh bags (mesh size of 2.5 cm by 1 cm) were assembled using standard leaf pack methods (Benfield, 1996) and placed in pools in the four streams on November 10, 2000. Three packs were removed on days 3, 7, 15, and 22 and five packs were removed on days 33 and 51. Four packs were processed on Day 0 to account for handling losses. Sediment was rinsed from packs and weighed, and macroinvertebrates were preserved for later analysis. Leaves were dried, ashed and weighed to determine ash-free dry mass remaining. Leaf breakdown rates were calculated using a standard exponential decay regression model (Petersen and Cummins 1974).

Temperature readings were taken hourly with Onset Corporation HOBO temperature loggers. Stream concentrations of nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), and soluble reactive phosphorus (SRP) were taken monthly and each day leaf packs were removed and analyzed using automated colorimetry using a flow analyzer (Greenberg 1992). Pesticide concentrations were sampled monthly in the water and sediment and analyzed using HPLC/MS techniques. Statistical analyses were conducted using JMP software (Version 3, SAS Institute).

RESULTS

NO_3-N, NH_4-N, and SRP were not significantly different between sites when compared using a one-way ANOVA. NH_4-N concentrations were highest at Keg Creek and Crabapple Creek but were frequently below the detection limit at all four sites (Table 1).

Hydroxychlorothalonil (degradation product of the fungicide chlorothalonil) was present in monthly water samples from every stream from July to October 2000. Although the levels detected are very low, we chose to look at this product because it was the one most frequently detected in these streams and chlorothalonil is commonly applied to suburban lawns. Concentrations of this fungicide were not significantly different between sites (Table 1). Hydroxychlorothalonil was also present in sediment samples from Oak Creek and Crabapple Creek in July with values of 30.7 and 32.7 μg/kg wet sediment, respectively. Hydroxychlorothalonil levels were detected below the limit of quantification in Keg Creek and Smoke Rise Creek sediments.

Accumulated degree days varied little between the streams during the experiment (Table 1). Temperatures were somewhat cooler in Keg Creek and warmer in Oak Creek.

After 51 days in the streams, the leaves in each of the four streams had breakdown rates that were not significanty different (95% confidence intervals of the rates overlapped, Table 1). However, the leaves in one of the reference streams, Keg Creek, had the lowest k-value of .006/day, while leaves in the other 3 streams had similar k-values of .011 to .012/day (Table 1).

DISCUSSION

The k-values measured at Oak Creek, Smoke Rise Creek, and Crabapple Creek are similar to breakdown rates for tulip-poplar leaves reported in the literature, of >0.01/day (Webster and Benfield, 1986). The slower k-value at Keg Creek of .006/day could be attributed to the lower number of accumulated degree days. High fungicide concentrations could also be causing the slower breakdown rate. However, concentrations of nitrate-N, ammonium-N, and SRP are highest at Keg Creek. Elevated nitrate concentrations have been found to lead to faster breakdown rates (Meyer and Johnson 1983).

Oak Creek and Smoke Rise Creek are deeply incised streams with high banks, showing evidence of high, flashy flows. There are numerous stormwater inputs,

Table 1. Degree days, leaf breakdown rates, average nutrient concentrations, and average hydroxychlorothalonil concentrations. Nutrients are reported as mean ± one standard error based on 8 samples. Hydroxychlorothalonil water sample concentrations are reported as mean ± standard error based on 4 samples. Leaf breakdown rates are ± 95% confidence limits.

Site[1]	Degree Day[2] (deg C)	Nitrate-N[2] (mg/l)	Ammonium-N[2,3] (mg/l)	SRP[2] (mg/l)	Hydroxy-Chlorothalonil[4] (ppb)	Leaf Breakdown Rate (day $^{-1}$)
Crabapple (R)	412	0.175 ± 0.038	0.007 ± 0.0007	0.006 ± .001	0.38 ± 0.105	-0.012 ± 0.005
Keg (R)	403	0.201 ± 0.035	0.0266 ± 0.0203	0.008 ± .002	0.442 ± 0.272	-0.006 ± 0.005
Oak (S)	469	0.196 ± 0.033	0.0051 ± 0.0005	0.007 ± 0.001	0.266 ± 0.065	-0.011 ± 0.005
Smoke Rise (S)	no data	0.147 ± 0.034	0.0056 ± 0.0007	0.005 ± 0.001	0.246 ± 0.089	-0.011 ± 0.006

[1] S= study site, R=mixed-use site
[2] From November to December
[3] Samples having values below the limit of detection were incorporated into the ANOVA as values equal to the detection limit.
[4] From July to October

and leaves are probably retained for only a very brief time. Therefore, leaf packs that are held in the reach become colonized by macroinvertebrates. In a sense they are food islands (Webster and Benfield, 1986) since the availability of food is limited due to rapid export downstream during storms. The aquatic insect community depends on leaf input as a significant energy source (Petersen and Cummins 1974).

When packs become buried, the leaves become part of an anoxic environment and microbes do not have access to oxygen to assist them in breaking down leaf material. Preliminary analyses do not suggest a statistically significant difference between streams for average sediment per pack. However, based on field observations of sediment deposition, we suspect that sediment deposition is going to play a larger role during the second half of the leaf deployment. In addition, some pesticides persist in sediments and we are seeing levels of hydroxychlorothalonil, chlorpyrifos, and oxadiazon at all four sites. The multiple factors of leaf pack burial with sediment, and sediment sequestering fungicides, could turn out to be the factors driving the slower breakdown rates at Keg Creek.

Leaf breakdown rates measured in this study are the product of several factors including temperature regime, burial by sediment, and invertebrate activity, which limit our ability to determine if there is an impact of pesticides or fertilizers applied to suburban lawns. Planned future laboratory studies of impacts lawn chemicals on leaf breakdown rates should help interpret the results of these field experiments.

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