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Leaf litter decomposition and microarthropod abundance along an altitudinal gradient

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Abstract

Mass loss rates of three types of leaf litter were measured along an altitudinal gradient at the Coweeta Hydrologic Laboratory, Macon County, North Carolina. Litterbags containing air dried litter from *Quercus prinus* L., *Liriodendron tulipifera* L., and *Rhododendron maximum* L. were placed in five plots along the gradient and sampled monthly. Microarthropods were extracted and sorted, and litter was weighed to determine mass loss. Decomposition rate constants were calculated for all litter types at each sample point along the gradient. Microarthropod abundance was also examined for all litter types across the gradient; the possible relationships of climatic factors to decomposition rates and microarthropod abundance were explored.

Introduction

Speculation on the effects of global warming has made clear the necessity of understanding how climate affects ecosystem processes. Gradients in altitude often produce climatic effects that would result from a latitudinal gradient, and so have been used as surrogates for latitudinal gradients. Study of ecosystem processes and community dynamics along a gradient may yield valuable insight on the response of system elements to climate. Little is known about the response of the soil biota to changes in climate, or of the possible effects of changes in the structure of the soil community on the process of decomposition.

Microarthropods play a critical role in decomposition and nutrient transformations (Abbot and Crossley, 1982; Hågvar, 1988, Seastedt and Crossley, 1980, 1988). Because they respond quickly to changes in their environment, there is growing interest in the possibility of using microarthropods as bioindicators of environmental stress or change (Cancela Da Fonseca, 1990; van Straalen et al., 1988; van Straalen, 1989).

This study was conducted at a Long Term Ecological Research site (Swank and Crossley, 1988) and had several objectives: (1) to measure the decomposition rates of leaf litter of varying quality across the altitudinal gradient, (2) to estimate the microarthropod abundances across the gradient, and (3) to explore the links between microarthropod abundance and decomposition dynamics.

Materials and methods

Site description

This study was carried out at the Coweeta Hydrologic Laboratory, Macon County, North Carolina. Five plots were established in order to investigate the effects of an altitudinal gradient on various ecosystem processes. These plots are located in an aggrading hardwood forest, range in elevation from 782 to 1347 m above sea level and are located on two watersheds, 18 and 27 (Table 1). While many of the watersheds at Coweeta have been used for experimental purposes, these two watersheds have served as undisturbed controls and have not been manipulated recently. Altitudinal gradients do not always result in climatic gradients; this may be due to topography, air drainage patterns, and seasonal effects, as well as other factors. In a windy area such as the Coweeta Basin, there is also much mixing of air. The plots used in this study did not lie along a distinct climatic gradient, but rather had differing microclimates.

Table 1. Selected site characteristics of the five altitudinal gradient stands at the Coweeta Hydrologic Laboratory

Site	Stand 118	Stand 218	Stand 318	Stand 427	Stand 527
Elevation (meters)	782	795	865	1001	1347
Aspect (degrees)	180	340	15	75	20
Slope (degrees)	34	21	34	33	33
Vegetation Type	pine-oak	cove hardwoods	mixed oak	mixed oak	northern hardwoods
Dominant Species	*Kalmia latifolia*	*Liriodendron tulipifera*	*Rhododendron maxima*	*Rhododendron maxima*	*Betula allegheniensis*
	Quercus prinus	*Quercus rubra*	*Quercus coccinea*	*Quercus rubra*	*Liriodendron tulipifera*
	Quercus rubra	*Tsuga canadensis*	*Quercus prinus*	*Carya* spp.	*Quercus rubra*
	Carya spp.	*Carya* spp.			
Moisture Reglme	xeric	mesic	mesic	mesic	mesic
Soil Type	Evard-Cowee gravelly loam; well drained	Evard-Cowee/ Saunook gravelly loam; well drained	Evard-Cowee gravelly loam; well drained	Chandler gravelly loam; somewhat excessively drained	Cullasaja-Tuckasegee complex; Plot fine sandy loam; moderately well drained

Experimental design

Litterbags (Crossley and Hoglund, 1962) were used to measure microarthropod abundance and mass loss of litter. Fresh leaf litter from three species, *Quercus prinus* L. (chestnut oak), *Liriodendron tulipifera* L. (tulip poplar), and *Rhododendron maximum* L. (rhododendron) was collected and air-dried. These species were chosen because they are abundant in these forests and range from easily decomposed (*L. tulipifera*) to recalcitrant (*R. maxima*) materials. Litterbags (15 cm × 15 cm) were constructed from fiberglass screening with a 1.5 mm mesh size. Approximately 2.5 g of leaf litter was weighed to the nearest 0.01 g and placed in each bag; a total of 180 bags of each litter type were constructed. Each bag had a numbered tag attached and initial weights were recorded.

Three 1 m^2 plots were established in each of the five altitudinal gradient stands, for a total of 15 plots. *R. maximum*, which has been suggested to be allelopathic and inhibit decomposition, occurred in each stand. Sample plot location was stratified so that within each stand, one 1m^2 plot was located near a rhododendron. The other two plots were located in areas that were representative of the stand, but not in close proximity to a tree or woody debris which could create additional microclimate differences. In December 1991, 36 litterbags, 12 of each litter species, were placed on the litter layer in each plot and anchored. The bags were then covered lightly with loose leaf litter from the forest floor.

Each month, one litterbag of each species was removed from each plot, for a total of 45 samples. Sampling began in January 1992 (one month after installation) and was carried out until December 1992. Litterbags were placed in plastic bags, sealed, and transported to the laboratory in a cooler. Microarthropods were extracted by placing the bags in modified Tullgren funnels (Mallow and Crossley, 1984) for not less than 5 days. Microarthropod samples were preserved in 95% EtOH. Litter was then removed from the bags and weighed to determine mass loss.

Decay constants are reported for each litter type in each stand using an exponential decay model (Olson, 1963). These constants were calculated by regressing $\ln(\text{mass}_o/\text{mass}_t)$ vs time, and are reported as annual values (Gallardo and Merino, 1993). Decomposition rates were compared as % mass remaining after one year of decomposition using ANOVA and the Student-Newman-Keuls (SNK) test. Microarthropod abundances were computed as the mean number of animals/gram litter (n=3 bags). The variances of the animal abundance data were not homogeneous, so a rank transform was performed on the data and the transformed data set was analyzed with parametric ANOVA (Conover and Iman, 1981). SNK tests were also performed on the rank transformed data.

Table 2. Decay constants for three types of litter along an altitudinal gradient, and comparison values from other Coweeta litterbag studies performed on mixed hardwood watersheds. Values are reported in years. Q P = *Quercus prinus*, L T= *Liriodendron tulipifera*, R M = *Rhododendron maximum*. The last two digits of the stand designation indicate the watershed; the first digit indicates the gradient plot number. Gradient plot 1 is the lowest elevation; plot 5 is the highest. The r2 values are for log-transformed data. Data sources: A: D. A. Crossley, unpublished data; B: Cromack and Monk, 1975; C: Seastedt, 1983

Stand/species	k value	r2	Watershed/Species	k value	Data Source
118 Q P	-0.33	0.81	7 Q P	-0.34	A
218 Q P	-0.18	0.48	2 Q P	-0.29	C
318 Q P	-0.42	0.87	18 Q P	-0.61	A
427 Q P	-0.31	0.75			
527 Q P	-0.27	0.86			
118 L T	-0.40	0.90	7 LT	-0.68	A
218 L T	-0.19	0.83	2 L T	-0.66	A
318 L T	-0.34	0.94			
427 L T	-0.38	0.92			
527 L T	-0.41	0.86			
118 R M	-0.23	0.82	7 RM	-0.16	B
218 R M	-0.14	0.87			
318 R M	-0.31	0.80			
427 R M	-0.32	0.80			
527 R M	-0.22	0.84			

Table 3. Comparison of % litter mass retained at the conclusion of the study, by litter type and gradient stand. Stand designations are as in Table 2. Means followed by the same letter are not significantly different at alpha = .05

Litter species	% mass retained	n	Stand	% mass retained	n
R. maxima	76.85 a	15	218	77.92 a	9
Q. prinus	67.81 b	15	527	71.06 b	9
L. tulipifera	67.04 b	15	118	70.26 b	9
			318	67.27 b	9
			427	66.30 b	9

Table 4. Comparison of microarthropod abundance by litter type and gradient stand. Data are # microarthropods gram litter. Stand designations are as before. Means followed by the same letter are not significantly different at alpha = .05

Litter species	Microarthropods per gram litter	n	Stand	Microarthropods per gram litter	n
L. tulipifera	101.41 a	60	427	109.39 a	36
Q. prinus	96.38 a	60	318	92.75 b	36
R. maxima	73.72 b	60	118	88.81 bc	36
			218	84.33 bc	36
			527	77.22 c	36

Table 5. Comparison of microarthropod abundance through time. Data are # microarthropods gram^{-1} litter. Means followed by the same letter are not significantly different at alpha = .05

Month	Microarthropods per gram litter		n
Jun	144.07	a	15
Aug	143.53	a	15
Jul	137.87	a	15
Nov	134.67	a	15
Sep	124.40	ab	15
Dec	110.20	b	15
Oct	61.93	c	15
Feb	58.73	cd	15
Apr	55.00	cd	15
Mar	52.27	cd	15
May	36.40	de	15
Jan	26.93	e	15

Results

Annual decay rate constants were calculated for all stands and litter types (Table 2). Both stand and species effects were significant; litter on Stand 218 retained a higher percentage of its initial mass while the other stands were not different (Table 3). *R. maximum* litter retained a higher percentage of its initial mass; *L. tulipifera* and *Q. prinus* litters did not differ significantly. Since plot placement varied from stand to stand, it was included in the model but was not found to be significant. There was no interaction between stand and litter species, so this term was not included in the model.

Animal abundances, as microarthropods/gram litter, were found to differ significantly through time, and among stands and litter species (Tables 4, 5). Stand 427 had higher abundances than the other stands and Stand 527 had lower abundances, although this was not statistically significant. Differences through time followed a seasonal pattern; abundances were higher in June-September, and the month of November also fell into this grouping. Abundances were lower in January and May. Among litter species, microarthropod abundance was significantly lower in *R. maximum* litter than in *Q. prinus* or *L. tulipifera* litter. Abundances did not differ between *Q. prinus* and *L. tulipifera*. Figure 1 shows microarthropod abundance, by litter type, for each stand.

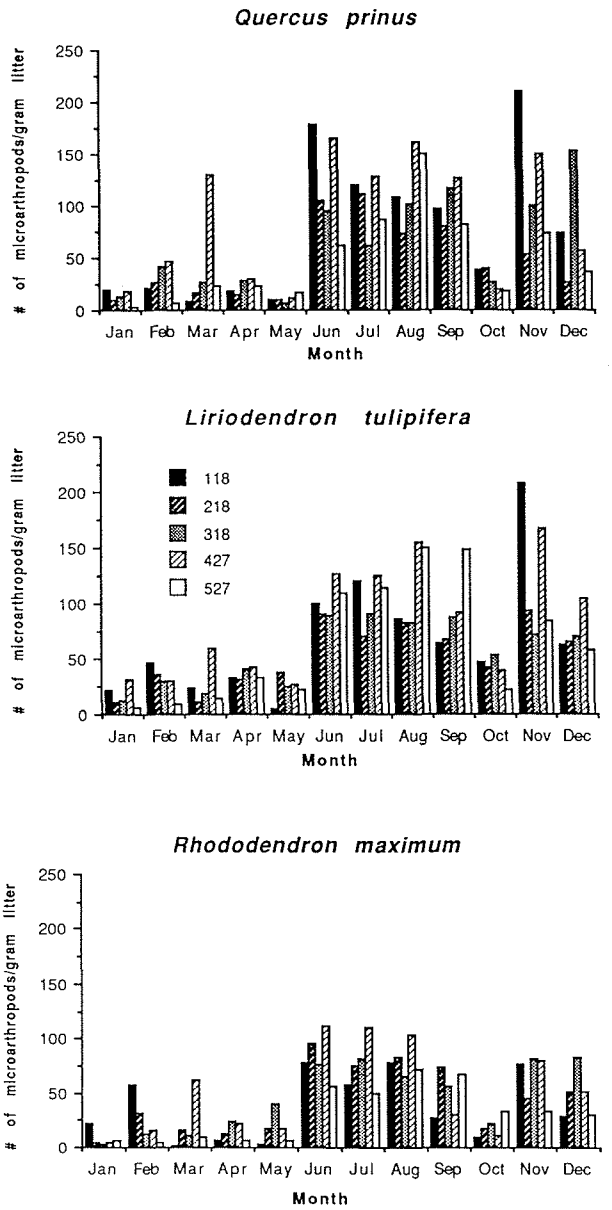

Fig. 1. Microarthropod abundance for each stand by litter type. Values are means (n=3) of # microarthropods gram^{-1} litter.

Discussion

Each of the five stands investigated occurs in different topographic, elevational positions and on different soils. Thus, each stand is subject to a different microclimate and it is reasonable to expect microarthropod abundance and the rates of litter decomposition to vary between the stands. Throughout the year, Stand 527 experiences the coldest temperatures (Fig.

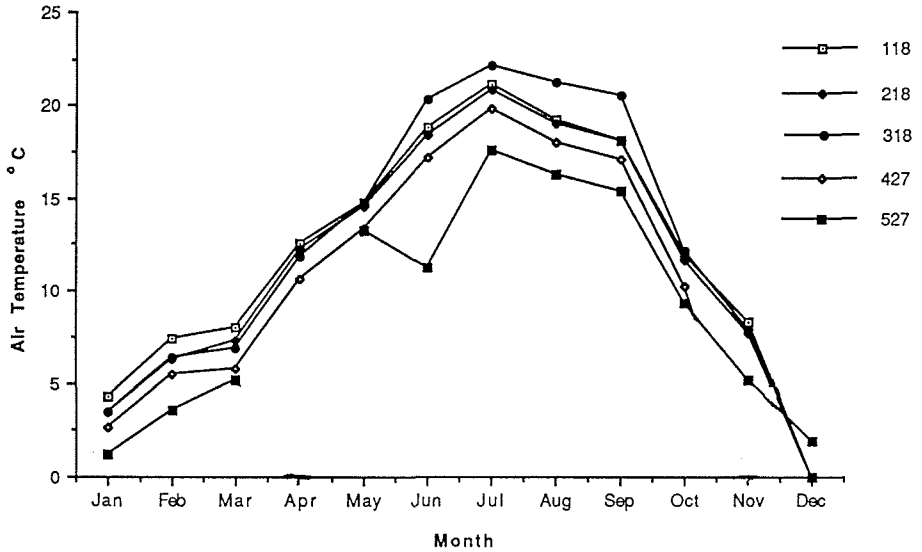

Fig. 2. Gradient stand air temperatures for 1992. Values are means of hourly readings for each month.

2) and is more exposed to wind; this stand had the lowest microarthropod abundances, and the second lowest (although this was not statistically significant) decomposition rates. The lowest decomposition rates occurred at Stand 218, a cove. Rainfall data are not available for the stands; however, this is the wettest site, with a seep occupying one corner of the stand. It is possible that decomposition rates were low because conditions were too moist. Microarthropod abundance was also fairly low here. In general, abundance was higher at the mid-elevation stands, 318 and 427, than it was at either the low elevation stands 118 and 218, or at the highest elevation (stand 527). This may be an effect of air drainage, where mid-elevation conditions are often ameliorated by adiabatic warming of air moving from above. Stand 427 had higher microarthropod abundances than any other stand; this appears to be a function of the deep litter layer which occurred in this stand. Because of its position, this stand is sheltered from wind and the loose litter remains intact for a longer period than on the other stands. This layer would tend to buffer microarthropod populations from temperature and moisture extremes, as well as physically increasing the habitat for mobile species and providing a large energy resource for decomposer organisms.

The pattern of temporal variation in the microarthropod data was typical, with the greatest abundances occurring in the summer months and in November, after litterfall. This pattern agrees with previous studies (Seastedt et al., 1983). Animal abundances increased significantly between the months of May and June. This coincides with the timing of canopy closure; the canopy protects the forest floor from direct sunlight and rapid dessication. The large increase in microarthropod abundance in December may be due to the extremely wet conditions that occurred in November and December.

Previous studies have shown that ericaceous plants such as *Rhododendron* contain a variety of phenolic compounds which are toxic to both plants and arthropods (Klocke and Kubo, 1991; Read, 1984). It is unlikely that all of these compounds are withdrawn from the leaf prior to abscission; some proportion remains in the litter, reducing its quality. One would therefore expect ericaceous plant litter to decompose more slowly and contain fewer microarthropods than a litter of higher quality. This is what we observed; the difference between *R. maximum* and the other two litters was highly significant for both abundance and decomposition .

Overall, it appears that both substrate quality and the microclimate of a forest stand have significant effects on both soil microarthropod abundance and decomposition rates. The annual decay constants reported here are lower than those previously reported for similar litters at Coweeta (Table 2); however, considerable interannual variability in nutrient loss rates has been reported (Sharpe et al.,1980) and it is reason-

able to expect that mass loss rates will display similar variability between years.

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