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Comparative Leaf Decomposition Rates Including a Non-Native Species in an Urban Ozark Stream

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Abstract

Leaf decomposition of three species of native Ozark vegetation was compared to that of one non-native invasive species. Leaves were placed in an urban gravel-bed stream for 23 days. Changes in mass and condition of the leaves were assessed along with stream temperature, flow, width, depth and discharge. Species native to Eastern North American forests were sycamore (*Platanus occidentalis)*, dogwood (*Cornus florida),* and redbud *(Cercis canadensis).* The non-native species, Japanese (Amur) honeysuckle (*Lonicera maackii)* comprised approximately 80% of the understory vegetation within the riparian zone of the study reach. After 23 days, Sycamore lost 24.6% mass, dogwood lost 30%, redbud lost 37.5%, and honeysuckle lost 38.3%. Sycamore leaves retained their relative structures the most (ranked 9 on a scale of 1 to 10, with 10 being the most sclerophyllous), and honeysuckle the least (ranked 2 on a scale of 1 to 10). As a result of this study, we suggest that the fast decomposition of leaves at southern latitudes may contribute to the low percentage of detritivores in streams, and that Japanese honeysuckle exacerbates this situation as a result of its more rapid rate of decomposition, therefore potentially depriving univoltine detritivores of nutrients later in their life cycles.

Introduction

Comparative leaf decomposition rates in streams among latitudes, stream types, ecoregions, disturbed/non-disturbed regions, and urban versus rural areas are of considerable interest due to the influence of decomposing leaves on stream community structure and function (Cummins 1974, Allan 1995, Tank et al. 2010). Leaf decomposition and processing rates are largely determined by the leaf species that accumulate in packs in the streams (Petersen and Cummins 1974, Tank et al. 2010). The different taxa of plants vary in toughness (sclerophylly) due to amounts and types of secondary chemical compounds (e.g., lignin, suberin, and cellulose) that make living plants able to more effectively resist decomposers and herbivores and therefore remain available in the stream for long periods of time (Turner 1994, Woodcock and Huryn 2005, Read and Sanson 2003). These differences in physical and chemical attributes are present in abscised leaves and slow their consumption by detritivores (Swan and Palmer 2006). Other secondary compounds that are part of a living plant's defense system have a chemical rather than physical mechanism of resistance (phenolics, tannins, irritants, allergens). However, these compounds are mostly water soluble and are removed by dissolution, so are less of a deterrent to aquatic detritivores (Hoorens et al. 2010).

Processing (colonization by microbes) is essential to enhancing the nutrient content of autumn-shed leaves (Petersen and Cummins 1974, Findlay 2010). Fallen leaves may vary in amount of nutrient content (nitrogen, phosphorus, and micronutrient compounds), and therefore differ in palatability to invertebrate consumers (Read and Sanson 2003, Pérez-Suárez et al. 2009). Sequestration of nutrients is common among plants that periodically shed their leaves (Horton and Brown 1991), so nutrients are reduced in all naturally abscised leaves. However, leaves and leaf parts (including frass) that enter streams as a result of insect activity in canopy trees, wind, and/or hail storms prior to abscission are more nutritious and are consumed faster by stream invertebrates (Horton and Brown 1991, Pérez-Suárez et al. 2009).

Decomposing leaves fuel most woodland stream communities and as the base of the food web are very important to community structure and function (Petersen and Cummins 1974, Swan and Palmer 2006, Pérez-Suárez et al. 2009, Hoorens et al. 2010). The community structure and function in Ozark streams is unique in that Nearctic fish species assemblages lack native detritivores and herbivores (Brown and Matthews 1995). As a result, consumption of decomposing leaves in Nearctic streams is primarily done by invertebrate detritivores. Shredding invertebrates, like any animals, need a good supply of nutritious food during their entire lives to live and grow, and if they exhaust supplies, must cease growing and perhaps die (Cummins 1974, Swan and Palmer 2006). In most northern temperate streams the leaves take a year or more to decompose or disappear (Peterson and Cummins 1974) allowing univoltine obligate detritivores to have some food available throughout their life cycles (Cummins 1974). The higher temperatures found in Ozark streams, on the other hand, result in faster decomposition rates thus causing faster depletion of allochthonous litterfall (Tank et al. 2010). Hydrological conditions that produce spiky hydrographs like those recorded in Ozark streams exacerbate the situation by transporting leaves from streambeds to the floodplains (Brown and Matthews 1995). The limited duration of leaf material in southern streams may partially explain the limited number, diversity, and biomass of detritivores (particularly shredders) (Brussock and Brown 1991, Brown and Matthews 1995, Brown et al. 2005).

Non-native invasive plants like the Japanese (Amur) Honeysuckle (*L. maackii*) have the potential to further alter the balance of detritus/detritivores in some southern streams where Japanese honeysuckle is becoming abundant in riparian forests (O'Connor et al. 2000, Collier et al. 2002, USDA 2010). Japanese honeysuckle is a large woody shrub that prefers open understory sites, especially in riparian areas (Collier et al. 2002, USDA 2010). Disturbances to natural forest communities make the forests vulnerable to colonization by this and other invasive plants (Collier et al. 2000). Dispersal of honeysuckle seeds by birds is common and it also spreads by sprouting from lateral growths of roots (Deering and Vankat 1999). This species is of concern as an aggressive invasive plant in at least 11 southeastern states including Arkansas (NRCS 2010, USDA 2010). Washington County, the location of this study, is among three counties in Arkansas that have been recognized by the Natural Resources Conservation Service and the United States Department of Agriculture as particularly vulnerable to infestation by this species (NRCS 2010, USDA 2010).

The objectives of this study were to 1) compare leaf decomposition of *L. maackii* to that of three species of flora native to Eastern North American forests and 2) to relate the decomposition rate of *L. maackii* to its potential impacts on nutrient availability for detritivores. The null hypothesis was that no significant difference would exist between the decomposition of *L. maackii* and that of the three native Eastern North American species, therefore having little or no effect on nutrient availability in the watershed and therefore having no impacts on detritivore assemblages.

Materials and Methods

Study area

This study was performed on Mud Creek, a second order stream in Fayetteville, Arkansas, which is a tributary of Clear Creek in the headwaters of the Illinois River watershed (36^0 06' 55.6" N and 94^0 07' 55.8" W). The Mud Creek watershed covers 43.49km^2 and land uses are predominantly urban (59.3%), forest (20.42%) and pasture (14.05%) (CAST 2006). The 29m reach used for the study was located alongside a suburban hiking trail and had at least 10m of riparian forest along both banks. The canopy cover consisted of deciduous trees including sycamore (*Platanus occidentalis*), oak (*Quercus spp.),* dogwood (*Cornus florida*), ash (*Fraxinus spp.*), redbud (*Cercis canadensis*), and maple (*Acer spp.*). *L. maackii* was prevalent along the stream segment and occupied approximately 80% of the riparian understory based on visual estimates. The stream had been heavily eroded as a result of channeling and bank alterations. Although it retained some riffle, pool, and flat habitats which are characteristic of gravel bed streams (Brussock and Brown 1991), substrate consisted of mostly bedrock and boulders with little gravel bedload remaining.

Leaf preparation and analysis

Four different species of leaves were compared in this experiment, three native species and one non-native species, respectively; 1) dogwood, 2) redbud, 3) sycamore, and 4) honeysuckle. Three leaf packs (three 4g leaf packs in 7 mm mesh) were prepared for each species from air-dried leaves that were harvested from trees in the study area just prior to natural abscission (Petersen and Cummins 1974, Wallace et al. 1982, Li et al. 2009). The leaf packs (12 in total) were secured with string to boulders along the side of the stream opposite the hiking path to discourage tampering. The leaf packs were placed by groups of four (one of each of the species) in three locations along the left bank where natural leaf accumulations existed and in areas of similar flow and depth. All of the leaf packs were removed after 23 days (6 October until 11 November). At that time, each pack was placed in individual plastic bags with watertight closure mechanisms and immediately returned to the lab where they were gently washed of sediment. Associated invertebrates were collected separately from each leaf pack and fixed in 70% alcohol for subsequent identification and counting. The leaves were air-dried and then weighed to assess loss of mass. Leaves were also qualitatively ranked on a scale of 1 to 10 to assess relative change in sclerophylly. This scale was based on relative comparisons between species after submersion in the stream. A score of "10" indicated the highest level of sclerophylly or no change in toughness. A score of "1" indicated very low sclerophylly wherein the leaf easily disintegrated upon handling after being submerged. Percent loss over time was calculated to establish rate of decomposition over 23 days and was calculated based on the methodology used by Petersen and Cummins (1974). We simultaneously measured physical and chemical conditions of the study stream to make the results more comparable with other studies. Invertebrates from the experimental leaf packs were assessed to determine the presence of detritivores.

Changes in the mass and structural integrity for each species were statistically compared through one-way ANOVA and Student's t-test analyses (α=0.05) (Maciá and Bradshaw 2000). Statistical analyses were conducted using JMP software.

Results

Mass losses after the 23 day experimental period for Japanese honeysuckle and redbud were significantly more (p=0.0055) than those for sycamore and dogwood (Table 1). Qualitative examination of the structural integrity of the leaves while still wet supported the pattern of decomposition seen in the mass loss results (p=0.0020). The honeysuckle and redbud leaves were in a more advanced stage of decomposition and their sclerophylly scores were lower than the other species receiving scores of 2.00 and 4.00, respectively. Sycamore and dogwood were more robust and more intact than the other species after the 23 days in the stream (Table 1). Leaf bag placement within the stream was not a factor in decomposition (p=0.7073). Macroinvertebrates were comparatively rare in the leaf packs, totaling 33 organisms overall. No detritivores were in the leaf packs. Average physical attributes of the selected stream reach were: discharge 0.28 $m^3 \cdot s^{-1}$, midstream flow rate 0.32 $m \cdot s^{-1}$, depth 40.84 cm, width 11.12 m, air temperature 13.50 ^{0}C, water temperature 14.03 ^{0}C. No spates occurred in the Mud Creek watershed during the 23 day field work portion of the study.

Table 1. ANOVA and t-test analyses of mass loss and structural ranking of four species of leaves after 23 days in an Ozark stream. Species with different letter (A, B) associations are statistically different. Loss/day and % loss (%R) indicate the rate of decomposition over 23 days.

Plant name	Student's t-test Statistical Association	Mean change in mass (g)	Mass loss/day (g)	% Loss	Mean condition (sclerophylly) ranking (scale 1-10)
Honeysuckle (*L. maackii*)	A	1.58	0.07	38.30	2.00
Redbud (*C. 94anadensis*)	A	1.55	0.07	37.50	4.00
Dogwood (*C. florida*)	B	1.24	0.05	30.00	7.33
Sycamore (*P. occidentalis*)	B	1.00	0.04	24.60	9.00
p value		0.0040	.0044	0.0055	0.0020
Standard error		0.0872	0.0038	2.1382	0.8819

Discussion and Conclusion

These results suggest that leaves of Japanese honeysuckle are among the fastest to decompose in an Ozark stream (Petty and Brown 1982, Brussock et al. 1988, Horton and Brown 1991, Li et al. 2009). Changes within southeastern riparian forests, such as those caused by invasive species like Japanese honeysuckle (Collier et al. 2001), have the potential to affect nutrient availability within stream ecosystems as a result of their rate of decomposition (Cornelissen and Thompson 1997, Rosemond et al. 2010). We observed, therefore, that since the honeysuckle plants decomposed rapidly and were found beside and overhanging the stream, they may affect detritivore population and nutrient availability within the stream. Although sycamore and dogwood were slower to decompose than the other two species, they would not be classified as slow by most investigators because leaf decomposition is rather fast at this southern latitude due to higher temperatures (Brown and Matthews 1995).

Diverse leaf packs provide nutrition over a longer period of time because leaves become or remain palatable at different times based on species-specific chemistry and tissue structure. This determines the amount of time detritivorous invertebrates have to take advantage of the decomposing allochthonous detritus. Generally, detritivores (especially shredders) are univoltine requiring long periods of growth to complete their life cycles. We suggest that the rapid decomposition of leaves at southern latitudes may contribute to the low percentage of shredders in Ozark streams and that Japanese honeysuckle exacerbates this as a result of its invasive characteristics and its rapid rate of decomposition.

We propose two potential effects that Japanese (Amur) honeysuckle could have on nutrient availability in Ozark streams. First, an abundance of relatively rapidly decomposing leaves in a stream during autumn could encourage growth of shredders and possibly other detritivores. However, invertebrates with longer life histories and thus longer periods of need for detritus, could be left without suitable food resources later in their development (Maciá and Bradshaw 2000). Since Japanese honeysuckle decomposes rapidly, its leaves may not support long-lived detritivores. On the other hand (and a potential topic for future research), these plants are understory shrubs and, as a result of their "shrub-like" structure, may trap leaves which fall from taller species of trees in the riparian zone (Horton and Brown 1991). We are not certain what effect this may have on the stream macroinvertebrates, if any, but suggest that the intercepted leaves may be released later and actually increase the period of time when leaves are available to stream detritivores despite their rapid rate of decomposition.

In summary, Japanese honeysuckle has the potential to affect nutrient availability by either shortening or lengthening the duration of the food supply within a stream. More research is needed to further explore the relationships. Removal of the invasive plants seems to be the correct course of action because of the potential impacts on leaf litter diversity (Cornelissen and Thompson 1997), but the overall impact of their presence on stream communities in the southeastern United States remains uncertain and more investigation is needed.

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