

# Impact of *Lonicera maackii* on Decomposition Rates of Native Leaf Litter in a Southwestern Ohio Woodland

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**ABSTRACT.** The potential for invasive non-native plant species to alter forest ecosystem dynamics is an increasing concern among ecologists. However, while it is clear that invasives have a detrimental impact on native plant species, less is known about how the invasives affect the host habitat. One hypothesis suggests nutrient dynamics at and below the soil surface may be critical. This study investigated the differences in leaf litter decomposition between *Lonicera maackii* (an invasive shrub) and two native woody species (*A. saccharum* and *Q. rubra*). We evaluated mass loss rates from each of the species examined as well as two-species combinations of litter (six treatment combinations) in *L. maackii* invaded and uninvaded areas of urban woodland in Cincinnati, Ohio. We found that *L. maackii* decomposed significantly faster than the two native species (e.g., 21 times faster than *Q. rubra*). Overall, there was a trend of faster decomposition in plots located in the invaded areas although this was statistically significant in only two of the six species combinations. The impact the observed differences in decomposition rates may have on nutrient dynamics and the advantages of accelerated nutrient turnover to *L. maackii* is discussed.

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## INTRODUCTION

Exotic invasive plant species are a ubiquitous component of terrestrial ecosystems today, one that often negatively influences natural habitats (Vitousek and others 1997) and is considered to be second only to habitat loss as a threat to biodiversity (Luken and Thieret 1997; Wilcove and others 1998). Invasive impact on ecosystem diversity and function varies depending on the species and the ecosystem; a multitude of studies document negative impacts ranging from reduced species diversity to changes in soil nutrient dynamics and hydrology (see Levine and others 2003 for review).

Invasion by exotic plants in the forests of southwestern Ohio is not a new phenomenon and, similar to habitats across the US, a mix of native and non-native species are found co-existing within these forest habitats. The forest habitat in the southwestern corner of Ohio has been significantly degraded by the exotic honeysuckle species, *Lonicera maackii*. *L. maackii* is a woody exotic shrub native to central and Northeastern China, Korea and Japan (Luken and Thieret 1996). The first evidence of this species in North America dates to the late 1890's when specimens were brought to Ontario, Canada and New York. It was originally used for ornamental purposes and to reduce soil erosion on steep slopes (Luken and Thieret 1996). In the US the first documented instance of escape was in Hamilton County, Ohio (Braun 1961). Currently *L. maackii* is present in at least 24 states on the east coast and Midwest as well as Ontario (Luken and Thieret 1996).

In much of Hamilton County, the site of the present study, *L. maackii* dominates the forest understory, forming dense thickets in many areas (B. Blair *pers. obs.*). Studies show that *L. maackii* negatively affects diversity and abundance of native herbaceous annual plants (Collier and others 2002; Gould and Gorchoff 2000; Miller and Gorchoff 2004), native tree seedling germination and survival (Collier and others 2002; Gorchoff and Trisel 2003), spider diversity (Buddle and others 2004), and herpetological diversity (McEvoy and Durtsche 2004), and may negatively affect bird species by causing increased predation of nesting birds by large mammals (Schmidt and Whelan 1999). However, less is known about the mechanisms by which *L. maackii* is altering the forest ecosystem and degrading growing conditions for native forest species, while

at the same time promoting its own survival and spread. *L. maackii* domination within Hamilton County's forests appears to be an example of an invasive species creating a self-sustaining positive feedback loop (Shea and Chesson 2002; Simberloff and Von Holle 1999).

Little research has been done on how this species affects ecosystem resources, particularly resources at and below the soil surface. There are reasons, however, to expect such changes. Nutrient cycling within ecosystems is dependent on the quality and quantity of leaf litter that falls to the ground and potentially the timing of leaf fall. These parameters strongly influence how fast nutrients are cycled through the ecosystem and the availability of nutrients to plants in the area (Eviner and Chapin 2003; Matson 1990; Meier and others 2006; Swift and others 1979).

Decomposition is controlled by climate (temperature and moisture availability), soil nutrients, the decomposer community and leaf chemistry (Swift and others 1979). Plant species composition is clearly important in determining leaf chemistry but also influences other factors. For example, while regional climate will determine average temperatures and precipitation of an area, local environmental factors also influence habitat micro-climate. Shading will determine the amount of light that gets to the understory influencing ground temperature and moisture availability at the soil surface.

Plants also affect the decomposition process directly through the quality of their leaf litter. Leaves that have a low C:N ratio (those relatively rich in nitrogen) are more readily degraded by fungi and bacteria and tend to be decomposed more quickly than leaves which have higher C:N ratios (Aber and Melillo 1991; Ehrenfeld and others 2001; Melillo and others 1982; Singh and Gupta 1977). Large molecular weight compounds found in leaves such as lignin also play a role in slowing down the decomposition process as decomposers must first release enzymes to break down these large molecules (Melillo and others 1982).

Thus, leaf litter decomposes at a rate determined by the environment and leaf chemistry. Several studies show that leaves of invasive species have a tendency to decompose more rapidly than native species (Allison and Vitousek 2004; Ashton and others 2005; Heneghan and others 2002; Standish and others 2004), and there is increasing evidence that these species alter the leaf litter decomposition rate of native species in the area possibly by altering

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the local microbial community (Ashton and others 2005; Ehrenfeld 2003; Standish and others 2004).

In order to quantify the affect of *L. maackii* leaf litter on leaf litter dynamics in this forest ecosystem we used a mesh bag technique to, (1) examine the effect of *L. maackii* on decomposition rates of native species leaf litter, and (2) determine how quickly *L. maackii* decomposes in comparison to dominant native tree species. We hypothesized that *L. maackii* would decompose at a faster rate than native species and that native species would decompose at a faster rate in the presence of *L. maackii*.

## METHODS

### Study Site

The study was conducted within the Spring Grove Woodland located in Cincinnati, Ohio (39.15°N 84.58°W, 235 m altitude). The forest is characteristic of the mixed hardwood second growth forests in the region and the overstory is dominated by *Quercus rubra* (red oak), *Acer saccharum* (sugar maple), *Fagus grandifolia* (American beech), and *Fraxinus americana* (white ash). Native woody understory shrubs include *Asimina triloba* (Paw Paw) and *Lindera benzoin* (spice bush). The soils of plots used in this study are silty loams in the Eden series and are classified as fine, mixed, mesic typic Hapludalfs. The area's mean monthly temperature is 12°C, and it receives an average annual precipitation of ca. 1000 mm.

### Experimental set-up

Six 4 x 5 m plots were created within the woodland. Three of the plots were in *L. maackii* thickets that formed a subcanopy at approximately 2.5 m above the forest floor (Lm plots). The remaining three plots were free of *L. maackii* (Lm-free plots). Freshly fallen leaves of *Q. rubra* and *A. saccharum* were collected from the study site in October of 2006. Due to their late leaf fall, leaves of *L. maackii* were collected, two months later, in early December. Intact leaves were air-dried but subsamples of each leaf type were dried to constant weight at 90° C to determine moisture content. A second subsample of each species was dried and then ground in a Wiley mill for analysis of total carbon and nitrogen (Thermo Flash 1112 CN analyzer).

Litterbags were constructed of nylon screen with a mesh size of 1 mm<sup>2</sup> and interior area of 225 cm<sup>2</sup> (15cm x 15cm). This mesh size allowed access by bacteria and fungi and micro-invertebrates but prevented larger invertebrates from entering. Bags were filled with 3g ca. of leaf litter consisting of a single species or two-species mixture of intact leaves (1.5g ca. of each species per bag) for a total of six treatments: (1) *L. maackii*, (2) *Q. rubra*, (3) *A. saccharum*, (4) *L. maackii* and *Q. rubra* (*Lm-Qr*), (5) *L. maackii* and *A. saccharum* (*Lm-As*), or (6) *Q. rubra* and *A. saccharum* (*Qr-As*). Sufficient litterbags were constructed (24 bags per treatment) to harvest one replicate of each litter type at four harvest dates from each of the six plots.

In February of 2007 four rows of six litterbags were arranged in each of the six plots. Leaves and twigs were removed from sites of litterbag placement. Leaf litterbags were then positioned on the surface of the mineral soil. Bags in a row were placed ca. 50 cm apart while rows were spaced 100 cm apart. These distances were chosen to assure individual litterbags were placed in a similar environment (e.g., same overstory trees) while minimizing the likelihood of influence of individual litterbags on each other. All litterbags were pinned to the soil using three-inch roofing nails to prevent movement. Rows contained one litterbag from each treatment in random order. This resulted in four replicates of each

litterbag treatment per plot. Litterbags were retrieved after 30, 90, 210, and 399 d of decomposition. At each of the four harvests one row of litterbags was removed from each of the six plots. Following retrieval, litter was carefully cleaned by hand to remove arthropods and loose soil debris and, dried at 90° C to constant weight and weighed. Due to soil accumulation on decomposing leaves, one bag of each treatment type was ground and ashed at 450° C for four hours after each harvest (Robertson and others 1999). This information was used to correct dry weights for soil contamination by multiplying dry weights by treatment specific percent ash-free dry mass (AFDM). All mass data are expressed on an AFDM basis.

### Statistical Analysis

To assist in comparison of litter decay rates we calculated the annual litter decay constant (*k*) for each litter type by fitting mass loss over time to a single negative exponential model (Olson 1963)

$$M_t = M_0 e^{-kt}$$

where  $M_0$  is the initial litter mass and  $M_t$  is the mass at time  $t$  in years.

Differences in relative decomposition rates between the treatments were determined by comparing the decay constant *k* (Robertson and others 1999) using ANOVA analysis. We then tested for differences in leaf decomposition rates between species and plots of different *L. maackii* status (*Lm* plots vs. *Lm*-free plots). Significant differences were identified using Tukey's HSD multiple comparison tests. All statistical analysis was done using SPSS 11.0 for Mac (SPSS Inc., Chicago, IL).

For leaf combination treatments (*Lm-Qr*, *Lm-As* & *Qr-As*) we calculated *expected* percent litter mass remaining at each of the four harvest dates. To accomplish this at each harvest we took the average of the applicable single species percent mass remaining. This technique was used to see if the presence of litter from one species influenced the decomposition of non- conspecifics.

## RESULTS

Total carbon and nitrogen leaf litter analysis revealed *L. maackii* to have relatively high quality leaf litter (low C:N ratio) when compared to *A. saccharum* and *Q. rubra* (C:N = 25 ± 1.6, 45 ± 3.5, and 101 ± 7.1, respectively). There was a consistent trend in litter decomposition rates (*L. maackii* > *A. saccharum* > *Q. rubra*) (Table 1). Of the three species examined, ANOVA analysis revealed significant differences in species decomposition rates (*k*) in plots where *L. maackii* was absent (*L. maackii*-free plots:  $F=10.46$ , d.f. = 8,  $p = 0.011$ ) and in plots where it was prevalent (*L. maackii* plots:  $F=159.66$ , d.f. = 8,  $p < 0.001$ ). According to the post-hoc Tukey's HSD test *L. maackii* decomposed more rapidly than *A. saccharum* and *Q. rubra* in both plot types and *Q. rubra* decomposed more slowly than *A. saccharum* in the *L. maackii* plots (Table 1, Fig. 1).

Comparison of *L. maackii* plots with the *L. maackii*-free plots found no significant difference in overall decomposition rates between plot types ( $F=3.20$ , d.f. = 35,  $p = 0.083$ ). However, when individual species were examined decomposition of *L. maackii* and the *Lm-Qr* combination were found to be significantly faster in the *L. maackii* plots (*Lm* -  $F=10.49$ , d.f. = 5,  $p = 0.032$ ; *Lm-Qr* -  $F=17.459$ , d.f. = 5,  $p = 0.014$ ). Other species and species combinations, while not significantly different, consistently trended towards faster decomposition in *L. maackii* plots (Fig. 3).

Leaf mixtures decomposed at rates that were intermediate compared to single species litterbags (Fig. 3). When *L. maackii* and *L. maackii*-free plots are combined, the percent litter mass

remaining of combination treatments (*Lm-Qr*, *Lm-As* & *Qr-As*) were similar to the calculated *expected* percent litter mass remaining at each harvest date (Fig. 2).

**DISCUSSION**

Our results clearly show a hierarchy in decomposition rates of the three species tested (*Lm* > *As* > *Qr*). *L. maackii* on average decomposed more than three times faster than *A. saccharum* and 21 times faster than *Q. rubra* (Table 1). This result is similar to other studies of invasive plant species, which found decomposition of invasive leaf litter faster than that of dominant native species in the area (Allison and Vitousek 2004; Ashton and others 2005; Heneghan and others 2002). Some differences have been even more substantial than those found here. For example Allison and Vitousek (2004) found up to a 50-fold difference in leaf litter decay rates between native and exotic species in Hawaii.

Two of the six leaf litter treatments (*L. maackii* leaf litter and *Lm-Qr*) showed significantly faster decomposition in *L. maackii* plots. However, all species and species combinations of leaf litter trended in the same direction, suggesting that litter decomposes more quickly in sites invaded by *L. maackii* (Fig. 3). Unfortunately, the relatively small number of replicates (three per plot type) was not sufficient to achieve statistical significance in the remaining litter treatments. It was observed in this and other forests in the region that standing leaf litter tends to be sparse in areas invaded by *L. maackii* throughout the year except during the period of peak litterfall in October and November (B. Blair pers. obs.). This is further anecdotal evidence that decomposition is accelerated in *L. maackii* invaded areas. Similarly, Ashton and others (2005) in a study on mesic hardwood forests in New York, found large differences in decomposition rates between leaves in forests invaded

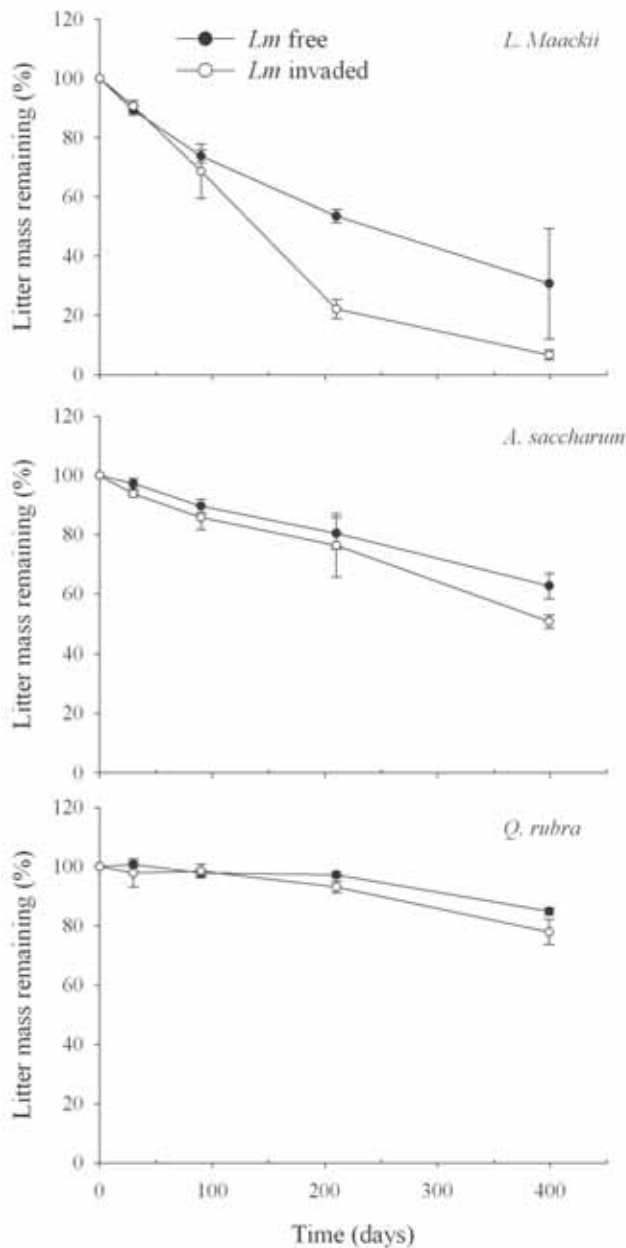


FIGURE 1. Mass loss (mean ± SE) of bagged leaf litter of three species placed in uninvaded forest plots (●) and plots invaded by *L. maackii* (○).

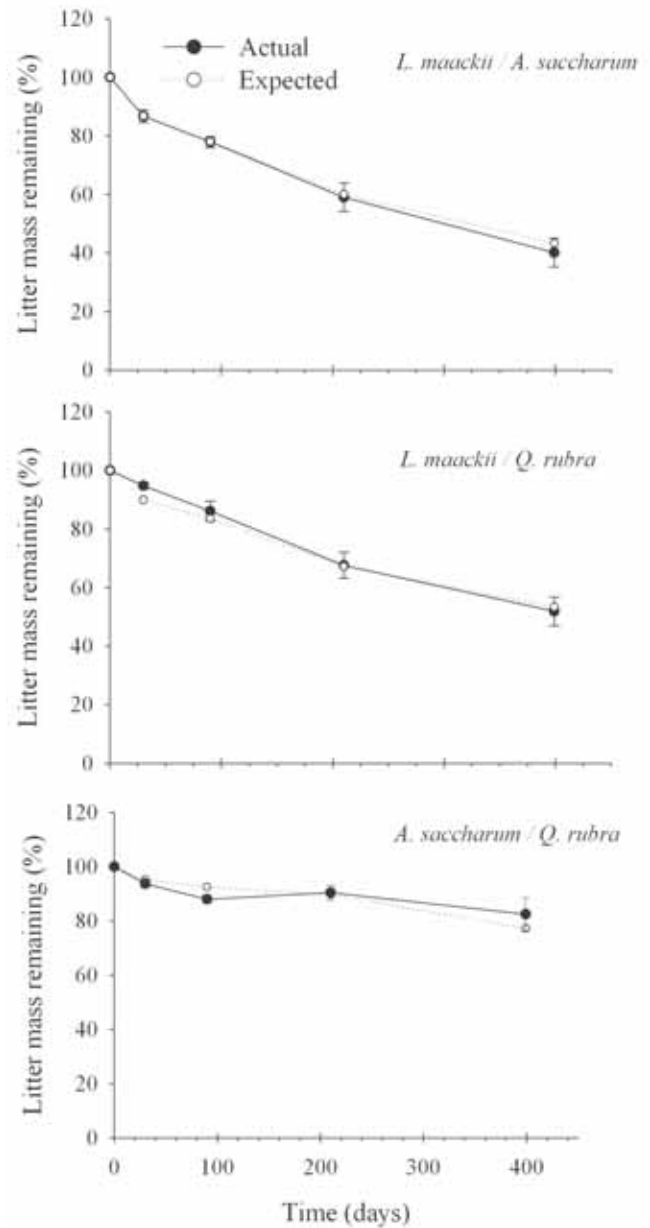


FIGURE 2. Mass loss (mean ± SE) of bagged leaf litter of species combinations (●) grouped across plot types, and expected mass loss (mean) of species combinations when individual species data are averaged (○). Expected mass loss was calculated by taking the average percent mass remaining at each harvest date of the two applicable single species treatments.

and uninvaded by *L. maackii*. In their study invasion status had a larger impact on decomposition rate than leaf type or status as an invasive species.

There are several possible explanations for why exotic invasive species tend to increase decomposition rates. One is simply that invasives are more palatable to decomposers due to potentially low C:N ratios, as observed in this study, and low lignin (or other recalcitrant components) in their leaves. Decomposers may then be able to sustain higher populations in the presence of invasive

species litter. The decomposers' larger population may account for increased decomposition rates for all species of litter in an area.

For example, it is known that non-native invasive earthworms can greatly increase forest leaf litter decomposition rates (Bohlen and others 2004; Suarez and others 2006) and studies suggest they are often more abundant in areas invaded by exotic shrubs (Heneghan and others 2006; Madritch and Lindroth 2009). One reason for earthworm co-occurrence with exotic shrubs may be their preference for litter with low C:N values (Hendriksen 1990). In a study by Madritch and Lindroth (2009) removal of Buckthorn (*Rhamnus cathartica*) and Bell's honeysuckle (*L. x bella*) reduced populations of invasive earthworms in a northern hardwood forest by almost 50 percent.

A second possibility is that the composition of the decomposer community fundamentally changes in the presence of the invasive species. Species of bacteria and fungi more able to take advantage of the invasive's leaf chemical composition, for example, may predominate in areas with heavy invasion. This difference in decomposer composition may be responsible for increased decomposition rates. Studies have shown that invasive species can have a strong influence on the soil biota (e.g., Heneghan and others 2004; Kourtev and others 2002; Wolfe and Klironomos 2005). Kourtev and others (2002) for example, demonstrated that two exotic invasive species, Japanese barberry (*Berberis thunbergii*) and Japanese stilt grass (*Microstegium vimineum*) alter the microbial

TABLE 1

Mean annual decomposition rate constants (*k*) for single species litterbags ( $\pm$ SE) in *L. maackii* dominated (*Lm*), *L. maackii*-free (*Lm-free*) and all plots combine (*Lm* + *Lm-free*). Decomposition rates were derived by fitting a single negative exponential model. Decomposition rates denoted by different letters in a given row are significantly different ( $P < .05$ ).

Treatment	<i>L. maackii</i>	<i>A. saccharum</i>	<i>Q. rubra</i>	P
<i>Lm</i> - plots	1.97 <sup>a</sup> (0.12)	0.51 <sup>b</sup> (0.06)	0.10 <sup>c</sup> (0.03)	<0.001
<i>Lm-free</i> - plots	1.02 <sup>a</sup> (0.26)	0.35 <sup>b</sup> (0.06)	0.06 <sup>b</sup> (0.01)	0.011
All plots combined	1.50 <sup>a</sup> (0.19)	0.43 <sup>b</sup> (0.06)	0.08 <sup>b</sup> (0.02)	<0.001

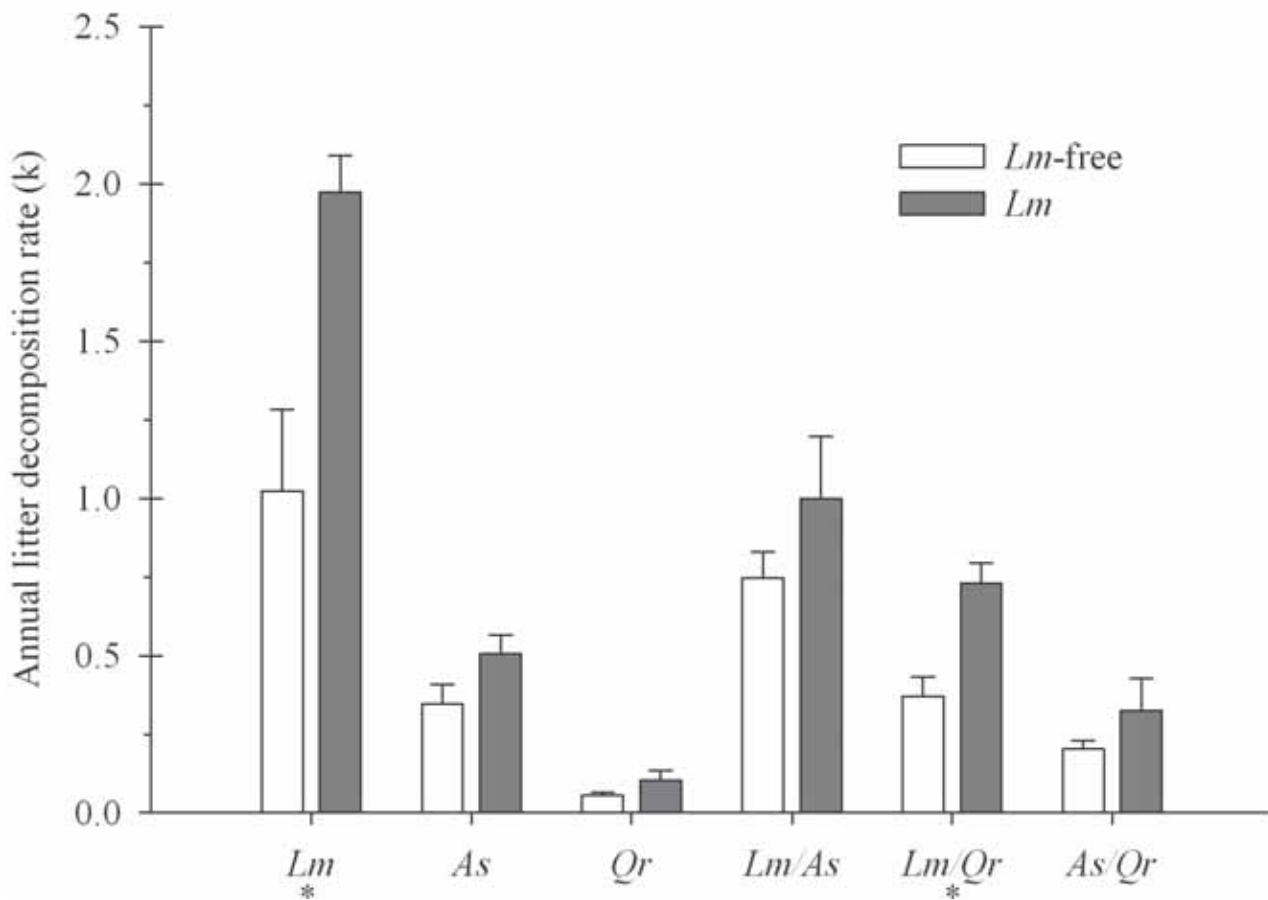


FIGURE 3. Mean annual decomposition rates ( $\pm$ SE) across all litterbag types in *L. maackii* dominated (*Lm*) and *L. maackii*-free (*Lm-free*) plots. Asterisk below species name represents significant difference between plot types ( $P < .05$ ). See text for species abbreviations.

community in Eastern forest soils. While many studies have found that invasive plants influence the microbial soil biota, none have examined the impact of soil biota alteration on litter decomposition. It is probable that both the effects of leaf chemical composition and the soil biotic community are significant and important in determining rates of decomposition.

The accelerated decomposition observed in the invaded sites may also have a significant impact on nutrient cycling by accelerating the transformation of nutrients to plant-available forms. Plants growing in the *L. maackii* invaded environment will potentially experience permanently increased plant-available soil nutrients since nutrients are tied up in leaves and other organic components for shorter periods. Ehrenfeld and others (2001), for example, in a second study examining *B. thumbergii* and *M. vimineum* found the invaders caused significant changes in pH, NH<sub>4</sub> and NO<sub>3</sub>. Higher nutrient availability favors fast growing invasive species (e.g., *L. maackii*) at the expense of slower growing native plants (Ashton and others 2005; Dukes and Mooney 1999).

Alternatively, *L. maackii* may cause greater seasonality in nutrient availability. Because *L. maackii* decomposes faster than competing species this may mean a relatively nutrient rich environment in the early spring during *L. maackii*'s initial leaf break and expansion but reduced availability at other times of the year. *L. maackii* leaf flush occurs several weeks earlier than most other woody plants in the region (Luken and Thieret 1996) so nutrient uptake competition is minimized during the early spring. This gives *L. maackii* the potential opportunity to draw-down nutrient stocks in the soil prior to competition with other local trees and shrubs. Further study is necessary to determine the nutrient dynamics in this particular system but positive feedback between an invasive species and the invaded habitat creates the potential for an invasive species to increase in dominance over time (Simberloff and Von Holle 1999).

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