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Comparing litter dynamics of *Phragmites australis* and *Spartina alterniflora* in a sub-tropical Chinese estuary: Contrasts in early and late decomposition

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ABSTRACT

Litter decomposition in communities dominated by emergent macrophytes can be considered a two-phased decomposition process, a standing phase followed by decay on the sediment surface. We examined the decomposition and nutrient dynamics in both phases of three structural components (leaves, flowers, stems) of two common emergent macrophytes in the Min River estuary, southeast China. The two species were *Phragmites australis*, a native species, and *Spartina alterniflora* an invasive one. Decomposition was slower in the standing phase compared to the sediment surface phase for most structural components of both species. In the standing and sediment surface phase, the exponential breakdown rates (*k*-value) for all structural components of *S. alterniflora* were much greater than the corresponding values for *P australis*. The *k*-values in different components of *P. australis* and *S. alterniflora* ranged from 0.96 to 1.79 $\times 10^{-3}$ d^{-1} and 1.67 to 4.58 $\times 10^{-3}$ d^{-1} in the standing phase, and from 1.60 to 5.32 $\times 10^{-3}$ d^{-1} and 3.05 to 6.93 $\times 10^{-3}$ d^{-1} in the sediment surface phase, for the two species, respectively. Over the 210 day study, the litter carbon concentrations in three structural components of *P. australis* fluctuated considerably compared to *S. alterniflora*. The variations in nitrogen concentration of flower and stem litter in both species experienced a similar pattern throughout the experimental period, in the sediment surface phase, although the nitrogen concentration increased in both species. Litter phosphorus concentration showed a completely different pattern between the two species throughout.

1. Introduction

Decomposition of plant litter and its consequences for litter accumulation are important components of ecosystem function, and as such, must play a crucial role in the global carbon balance (Tuomi et al., 2009). Decomposition is the process through which organic matter is converted into forms that primary producers can re-use (Park and Cho, 2003), and can potentially limit ecosystem productivity. It is, therefore, important to understand nutrient cycling through its complete pathway; from senescence of plant material to decaying plant detritus in the soil.

Wetlands represent the largest component of the terrestrial biological carbon pool (Dixon and Krankina, 1995). In spite of this, most decomposition studies have been performed in terrestrial systems where the pre-dominance of aerobic conditions generally results in rapid decomposition of plant debris. In wetlands, however, decomposition occurs at significantly lower rates due to anaerobic conditions throughout the soil profile brought about by flooding at different frequencies and lengths of duration (Debusk and Reddy, 2005). Past studies of litter decomposition in wetlands have been mainly focused at the sediment surface (Liao et al., 2010; Guo et al., 2008; Song et al., 2011). However, for emergent macrophytes the abscission and collapse of leaf and culms to the sediment surface does not occur immediately after senescence/death, and considerable microbial colonization and subsequent mineralization of standing emergent macrophyte litter may occur before it arrives at the sediment surface (Kuehn and Suberkropp, 1998; Asaeda et al., 2002; Kuehn et al., 2004). Despite this evidence, some uncertainty remains about litter decomposition dynamics in wetlands, especially on the relative importance of decomposition whilst litter remains in the standing phase (spring- and early-summer period) compared to when it becomes incorporated into the sediment surface vegetation (autumn- and winter-period).

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Litter decomposition rates and associated nutrient dynamics also depend to a large extent on intrinsic chemical properties of the plant detritus material (e.g., carbon (C), nitrogen (N) and phosphorus (P) concentrations) (Enríquez et al., 1993; Lee and Bukaveckas, 2002), but environmental factors (temperature, soil moisture content, availability of nutrients) have also been shown to be important (Debusk and Reddy, 2005). For estuarine marshes, the frequency and duration of inundation is a key environmental factor as it provides differential conditions of exposure to saline, brackish or fresh water. This frequent inundation will affect the temperature regimes the plants and decomposers experience in both water and air, and hence will affect decomposition in some way. In addition, inundation will affect different parts of emergent macrophytes in different ways as the lower parts of the stem are submerged for a greater period than the upper parts; it's important to know about how decomposition varies with respect to stem height.

Here, we compared the litter decomposition rates and associated nutrient dynamics of six plant parts of two species; a native one *Phragmites australis* Trin, and a recently introduced one *Spartina alterniflora* Loisel in the Min River estuary, south-east China. In 1979, *S. alterniflora* was introduced deliberately to Luoyuan Bay on the Fujian coast, in order to provide increased protection of coastal banks, and to accelerate sedimentation and land formation (Liao et al., 2008). From there, *S. alterniflora* started to invade the Min River estuary in 2002, and it has since formed mono-specific stands. This rapid spread of *S. alterniflora* has been identified as one of the most damaging impacts for the conservation of native plant communities in the estuaries of south-east China (Deng et al., 2006). *S. alterniflora* started to invade the Min River estuary in 2002, and it has since formed mono-specific stands.

The aim here was to quantify the two-phased decomposition process (standing and sediment surface) within communities dominated by *P. australis* and *S. alterniflora*. We tested five hypotheses, i.e., that decomposition rates would: (1) differ in the standing- and sediment surface-phases, (2) vary between the different plant parts, (3) vary according to their vertical height in the stand during the standing-phase, which reflect differences in inundation, (4) be affected by resource quality, and (5) vary between the two species.

2. Methods

The study site was located within the Shanyutan wetland (Longitude, 119°34′12″–119°40′40″ E; Latitude, 26°00′36″–26°03′42″ N) on the Min River estuary, southeast China. The estuary has typical semi-diurnal tides, a mean annual temperature of 19.6 °C, and a mean annual precipitation of 1346 mm. Within this wetland, two adjacent communities (25 m apart) were selected for litter collection and the decomposition experiment: one dominated by *P. australis* and the other by *S. alterniflora*. The height range for both species is typically between 160 and 180 cm.

2.1. Sample collection and preparation

In December 2009, at the end of the growing season when natural senescence starts, standing dead litter of both *P. australis* and *S. alterniflora* was collected to provide the test material for evaluating litter decomposition and nutrient release rates. In the laboratory, these samples were first washed with filtered stream water and then with deionized water to remove attached sediments and invertebrates, and then separated into different plant structural components (flower, leaf and stem). The stem was further sub-divided depending on the length of the standing dead stem, i.e., into 0–30, 30–80, 80–130, 130–180 cm sections; these were then cut into 10 cm long pieces. All material was then air-dried for several weeks and then dried to a constant weight at 70 °C to ensure a constant starting material (following Kuehn et al., 1999; Xie et al., 2004; Álvarez and Bécares, 2006; Liao et al., 2008; Sun et al., 2012; Song et al., 2011). Litter-bags (25 cm × 30 cm) made of fiberglass 0.3 mm mesh were filled with individual litter components (20 g for leaf and stem; 10 g of flower); 252 bags were produced, i.e., 2 sites/species × 6 components × 7 time samplings × 3 replicates. The litter bags were then returned to their respective communities (i.e., *P. australis* litter to the *P. australis* community; *S. alterniflora* litter to the *S. alterniflora* community). The litter bags were retrieved in two phases to reflect the standing and surface phases of decomposition as follows:

Phase 1: *Standing-phase decomposition*. On March 12, 2010, at the start of the growing season, 2 m tall canes were positioned in the center of each plant community. Litter-bags were tied to these canes at the positions within the height range of the natural standing dead litter. Litter-bags of each type were then retrieved at 0 (no decomposition), 15, 30, 45, 60, 75 and 90 days.
Phase 2: *Sediment surface-phase decomposition*. On June 12, 2010, mid-way through the growing season, the remaining litter-bags were transferred to random positions on the sediment-litter layer of the marsh. Litter bags of each type were retrieved from the wetland at 30-day intervals, i.e., 120, 150, 180 and 210 days after the start of the experiment.

After retrieval and transfer to the laboratory the litter remaining in all bags was carefully separated, washed and dried as described above. Thereafter, the total carbon (TC), total nitrogen (TN) and total phosphorus (TP) concentrations were determined on each sample. The C and N contents of plants and litter were determined using a Vario EL III Elemental Analyzer (analytical error ≤ 0.3%), while P concentrations of all litter samples were determined by molybdate-ascorbic acid colorimetry (digested by H_2SO_4–$HClO_4$), P concentration was measured colorimetrically at 700 nm after reaction with molybdenum blue (analytical error ≤ 5%) (Watanabe and Olsen, 1965).

2.2. Statistical analysis

Regression analysis (function 'lm', R Development Core Team, 2011) was used to assess the relationship across the entire experiments; here simple linear and second-order polynomial equations were fitted. The proportion of mass remaining at the end of the experiment (P_{210}) and the time for 95% of the starting litter dry mass to decompose were also calculated ($t_{0.95}$) for each plant fraction. Thereafter, for organic matter loss, *k*-values (Olson, 1963) were calculated for each phase of the study (k_1 = standing phase (0–90 days)); k_2 = sediment surface phase (90–210 days) using the simple exponential model (Eq. (1)):

$$\log_e\left(\frac{L_t}{L_0}\right) = -kt \quad (1)$$

where L_t is the litter dry mass remaining after t day decomposition, L_0 is the litter dry mass at the start of each phase, K is the decomposition rate or exponential breakdown coefficient and t is the duration (in days) of decomposition. For Phase 2, L_0 was set to the mean value of the mass in the 90-day samples (end of Phase 1, start of Phase 2). An analysis of covariance was also performed to test for differences in k values between the two phases for each plant part for each species. In this analysis *P. australis* was set as the intercept (Crawley, 2007). Bonferroni correction was used to adjust for the Type I error rate (Cabin and Mitchell, 2000; Sokal and Rohlf, 1995).

Differences in dry mass remaining, litter nutrient concentrations among plant parts, plant species and the two phases of decomposition were examined by least-significant difference (LSD)