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Dynamics of litter decomposition of dieback *Phragmites* in *Spartina*-invaded salt marshes

Hui Li[a,b], Yazhu Liu[b], Jing Li[b], Xuhui Zhou[b], Bo Li[b,*]

[a] College of Life and Environment Science, Shanghai Normal University, #100 Guilin Road, Shanghai 200234, PR China
[b] Coastal Ecosystems Research Station of Yangtze River Estuary, Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, Institute of Biodiversity Science, Fudan University, #2005 Songhu Road, Shanghai 200438, PR China

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ABSTRACT

Vegetation dieback can alter plant population dynamics and community structure, however, its impact on litter decomposition has been poorly understood. The litterbag method was employed to examine effects of reed dieback on litter decomposition of native *Phragmites australis* in the *Spartina alterniflora*-invaded Chinese salt marshes. Compared with healthy *Phragmites*, the initial C and N contents in leaf, sheath and stem of dieback *Phragmites* were significantly higher (for all $P < 0.001$, except N content in stem $P > 0.05$) and their initial C:N ratios were significantly lower ($P < 0.05$). Moreover, the aerial stem litter of dieback *Phragmites* decomposed significantly faster than that of healthy *Phragmites* ($F_{1,46} = 5.784$; $P < 0.05$). During the 310-day decomposition, the C:N ratio in dieback *Phragmites* was significantly lower than that in healthy *Phragmites* ($F_{1,273} = 28.510$, $P < 0.001$) and the remaining N concentrations of the two types of *Phragmites* were significantly different from each other ($F_{1,270} = 16.316$, $P < 0.001$). Only the N content in leaf tissue of dieback *Phragmites* decreased continuously, while it changed up and down in other tissues. Our results suggest the significance of integrating vegetation dieback into the ecosystem processes and the vegetation and land-surface models, as well as the management strategies on protecting the susceptible ecosystems.

1. Introduction

Vegetation dieback has been observed in various ecosystems, such as stand-level dieback and sudden oak death in forests (Mueller-Domobois, 1986; Rizzo and Garbelotto, 2003), reed dieback and sudden marsh dieback in wetlands (Brix, 1999; Alber et al., 2008). This phenomenon has become more widespread under global change than ever before (Allen et al., 2010; Lloret et al., 2012). Recently, much progress has been made in exploring the mechanisms of vegetation dieback, including the effects of abiotic environment (e.g., Armstrong and Armstrong, 2001; Duarte et al., 2013), biotic factors (e.g., Ahmad et al., 2013; Li et al., 2014) and combined effects associated with human activities (e.g., Altieri et al., 2012; Coverdale et al., 2013). However, the major impacts of vegetation dieback on ecosystems have been far less recognized, although its consequences (e.g., economic and social) are receiving increasing attention (Silliman et al., 2005).

Vegetation dieback cannot only affect plant population dynamics through disturbing individual growth and recovery (Swiecki and Bernhardt, 2002; Altieri et al., 2013) and changing soil properties critical to plant survival (Crawford and Stone, 2015), but also change community composition and structure in many different ways, e.g., regulation of species interactions (Hudson and Greenman, 1998; Li et al., 2013) and trophic cascade (Rizzo and Garbelotto, 2003; Altieri et al., 2013). Lately, the results from comparative tests on differences of organic and inorganic components in soil and water at dieback and healthy sites show that vegetation dieback is likely to alter ecosystem processes (Ágoston-Szabó and Dinka, 2009). However, experimental evidence has been still scarce.

Salt marshes providing important ecosystem services have been seriously threatened by vegetation dieback (Alber et al., 2008). The Dongtan wetland in the Yangtze River estuary has recently experienced reed (*Phragmites australis*, hereafter referred as to *Phragmites*) dieback since 2008. Reed dieback leads to the rapid death of *Phragmites* from the top downwards at the end of vegetative growth, which blocks the translocation of photosynthetic production to below-ground tissues, possibly resulting in more carbon retention in above-ground tissues. Moreover, such sudden

* Corresponding author.
E-mail address: bool@fudan.edu.cn (B. Li).

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death of the young tissues at the top can still retain available nutrients (e.g., nitrogen) in the dead tissues, which causes a higher N content in dieback tissues than in senescent ones. Accordingly, litter quality of *Phragmites* may be altered due to the dieback event. Nevertheless, the impacts of reed dieback on litter decomposition have been poorly understood.

Litter decomposition is a pivotal ecosystem process closely tied to carbon transformation and nutrient cycling (Begr and McClaugherty, 2008). It is controlled not only by litter quality but also by characteristics of microbial community and physical environment (Begr and McClaugherty, 2008; LeRoy et al., 2014; Rinkes et al., 2014). In the Yangtze River estuary, the native *Phragmites* communities have been seriously invaded by non-native *Spartina alterniflora* (hereafter referred as to *Spartina*), which has altered the local litter pools and litter decomposition (Liao et al., 2008). Recently, the impacts of *Spartina* invasion on the ecosystem functioning in the Dongtan wetland may become more notable due to the occurrence of reed dieback which is possibly related to an endophytic fungus *Fusarium palustre* of the invasive *Spartina* (Li et al., 2014). As the reed dieback has continued to spread and accelerated the local community succession via reducing the relative competitive advantage of native *Phragmites* but favoring *Spartina* invasion (Li et al., 2013), studies dealing with the responses of local ecosystem processes to invasion are needed to consider the role of reed dieback. Here, we hypothesized that reed dieback may alter the litter decomposition of native *Phragmites* in the salt marshes invaded by *Spartina*. To test this hypothesis, we addressed the following questions: (i) is the litter quality of dieback *Phragmites* different from that of healthy *Phragmites*? (ii) Does the litter of dieback *Phragmites* decompose differently from healthy *Phragmites*?

2. Materials and methods

2.1. Study site

This study was conducted in Dongtan wetland on Chongming Island in the Yangtze River estuary, Shanghai, China (31°25′–31°38′N, 121°50′–122°05′E), which is recognized as a 'Wetland of International Importance' and is set aside as a National Nature Reserve for migratory birds. The island has a northern subtropical monsoon climate with the mean annual temperature of 15.3 °C and the average annual precipitation of 1022 mm, most of which occurs in the summer (Xu and Zhao, 2005). The whole wetland encompasses a total area of 32,600 ha and consists of shallow water, muddy flats and salt marshes that are dominated by native sedges (e.g., *Scirpus* spp. and *Carex* spp.) and *P. australis*, and non-native *S. alterniflora*. *Spartina* invades or surrounds native *Phragmites* communities, forming two-species mixtures or mosaics of their pure patches in the salt marshes where *Phragmites* has been experiencing dieback (Li et al., 2013).

2.2. Sampling and litterbag preparation

The aboveground litter samples of dieback *Phragmites* in dieback patches and of healthy *Phragmites* in its pure communities were separately collected on November 24th and on December 24th, 2011, given that the two types of *Phragmites* wilted in early September and mid-October, respectively. Senescent *Phragmites* shoots with leaves ready to fall were cut off at ground level. Dieback (or healthy) *Phragmites* litter was collected from a variety of dieback (or healthy) patches in the Dongtan wetland and then mixed. All litter samples were separated into leaf blade, leaf sheath and stem, and carefully washed with tap water immediately after collection. They were cut into 5 cm pieces and oven-dried at 50 °C to constant weight. Random subsamples of the oven-dried leaves, sheathes and stems were used to estimate the initial C and N contents. These subsamples were smashed with a Wiley mill, ground into powder and sieved (mesh size 0.15 mm). The initial C and N contents of litter were analyzed by NC Soil Analyzer (Flash EA 1112 Series; Thermo Finnigan, Elk Grove Village, IL).

The nylon litterbag of 20 cm × 25 cm with a mesh size of 0.3 mm × 0.3 mm was used to quantify litter decomposition. The mesh size was small enough to reduce the physical loss of litter and the intervention of macro-invertebrates (e.g., crabs, spiders and snails), but water, sediments and microbes could pass through the litterbags freely. Each litter sample of 10.1 g was individually confined in the litterbag which was sealed with nylon strings. All samples were replicated four times and a total of 384 litterbags were prepared.

2.3. Litter decomposition

In order to minimize the effects of environmental heterogeneity on litter decomposition, two types of community with three replicates (six plots in total) which possessed similar environmental variables (e.g., oxidation reduction potential, electric conductivity, pH, water content and light intensity; Li et al., 2013) were established at the same elevation in February 13th, 2012, including the dieback community with dieback *Phragmites* and healthy *Spartina*, and the healthy community with both healthy *Phragmites* and *Spartina*. The nearest distance between the plots was *c.* 20 m which was distant enough to minimize the spatial autocorrelation between these plots. A few crabs, spiders and snails were found in all the plots. The dieback and healthy *Phragmites* litterbags were accordingly laid in the dieback and healthy communities. To fix litterbags for aerial decomposition in each plot, two 1.5 m long bamboo rods with a distance of 1.5 m were inserted into the sediment, on which one 1.7 m long bamboo rod with 1.5 m height above the sediment surface was fixed. A nylon string bound with litterbags was tied onto the two 1.5 m long bamboo rods at ground level in each plot and used for surficial decomposition.

Fig. 1. The decomposing litters in the dieback community suffering reed dieback (A) and the healthy community (B). Photos were taken on July 3rd, 2012.