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Effects of nutrient enrichment on mangrove leaf litter decomposition

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HIGHLIGHTS

- Microbial decomposers are N-limited even in sites where tree growth is P-limited.
- Eutrophication increased mangrove litter decomposition exclusively via litter quality.
- Litter N and P dynamics were not modified by external amendments.
- Eutrophication effects on decomposition may depend on limitation of primary producers.
- Litter N and P dynamics were not modified by external amendments.

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ABSTRACT

Nutrient enrichment of mangroves, a common phenomenon along densely populated coastlines, may negatively affect mangrove ecosystems by modifying internal carbon and nutrient cycling. The decomposition of litter exerts a strong influence on these processes and is potentially modified by eutrophication. This study describes effects of N and P enrichment on litter decomposition rate and mineralisation/immobilisation patterns.

By making use of reciprocal litter transplantation experiments among fertiliser treatments, it was tested if nutrient addition primarily acts on the primary producers (i.e. changes in litter quantity and quality) or on the microbial decomposers (i.e. changes in nutrient limitation for decomposition). Measurements were done in two mangrove forests where primary production was either limited by N or by P, which had been subject to at least 5 years of experimental N and P fertilisation.

Results of this study indicated that decomposers were always N-limited regardless of the limitation of the primary producers. This leads to a differential nutrient limitation between decomposers and primary producers in sites where mangrove production was P-limited. In these sites, fertilisation with P caused litter quality to change, resulting in a higher decomposition rate. This study shows that direct effects of fertilisation on decomposition through an effect on decomposer nutrient availability might be non-significant, while the indirect effects through modifying litter quality might be quite substantial in mangroves. Our results show no indication that eutrophication increases decomposition without stimulating primary production. Therefore we do not expect a decline in carbon sequestration as a result of eutrophication of mangrove ecosystems.

1. Introduction

Mangroves are among the most carbon-rich forests in the tropics (Donato et al., 2011), due to high primary production and slow decomposition (Cebrián, 1999). The latter process governs important ecosystem services such as soil carbon sequestration and nutrient exchange with through-flowing water. Microbial decomposers are a key functional group processing most of the carbon and nutrient fluxes in these coastal systems (Holguin et al., 2001). Leaf litter is a primary resource for decomposers, and its quality and quantity have strong effects on decomposer activity (Couteaux et al., 1995; Strickland et al., 2009; Mooshammer et al., 2012). Decomposers have a major impact on nutrient availability for the vegetation through conversion of organically bound nutrients to mineral forms (mineralisation) and vice-versa (immobilisation) (Swift et al., 1979; Berg and Laskowski, 2005; Cherif and Loreau, 2009) As a change in nutrient availability in turn affects both litter composition and litter production rate, changes in decomposition dynamics have a strong potential feedback on the decomposer community composition, nutrient availability, and primary production (Holguin et al., 2001; Hessen et al., 2004; Norris et al., 2012).

The rate of decomposition generally correlates positively with nutrient availability in terrestrial and wetland ecosystems (Cebrián et al., 1998). Anthropogenic nutrient enrichment might therefore have a

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negative effect on carbon storage by stimulating decomposition more strongly than primary production (Hessen et al., 2004). Nutrient enrichment may change litter decomposition in two different ways, i.e. directly, via increased availability of mineral nutrients for decomposers (Norris et al., 2012), and indirectly, via fertiliser-induced changes in litter composition (Bryant et al., 1983; Prescott, 2010; Hobbie et al., 2012). Indirect effects of nutrient enrichment may include an increase in litter nutrient content (Hobbie et al., 2012) and a decrease in carbon-rich secondary compounds such as lignin (Bryant et al., 1983), both resulting in a higher decomposability.

Direct effects of nutrient enrichment on decomposition are quite complex, as both retarding and stimulating effects of nutrient amendment have been reported. While decomposition of labile litter compounds is mostly stimulated by nutrient addition, the effect on more recalcitrant litter compounds is element specific, as nitrogen generally retards, (O'Connell, 1993; Knorr et al., 2005; Craine et al., 2007), while phosphorus stimulates breakdown of these litter compounds.

Nutrient enrichment thus affects decomposer activity, litter quality, and their interaction. Nutrient availability and litter quality influence patterns of nutrient immobilisation and mineralisation during decomposition, (O'Connell, 1993; Osono and Takeda, 2004). As these processes are tightly coupled to nutrient uptake by mangrove trees (Holguin et al., 2001), changes in nutrient dynamics of decomposing leaves may have important consequences for primary production. Nutrient enrichment therefore could result in complex interactions culminating in net accumulation or net loss of litter and soil organic matter in the soil. For example, enrichment in one nutrient may decrease availability of another nutrient through plant uptake or immobilisation. This, in turn, may slow down decomposition, primary production, or both.

In the present study, we investigated the effects of long-term nitrogen (N) and phosphorus (P) enrichment on patterns of litter decomposition as well as nutrient mineralisation and immobilisation in two mangrove forests on Twin Cays in Belize and on North Hutchinson Island in Florida. These mangroves have a contrasting soil carbon content, but a similar vegetation structure with trees fringing the coastline being much taller than trees growing further inland. In this very nutrient-limited inner zone, mangrove trees are stunted and growth is limited by P on Twin Cays and by N on North Hutchinson Island.

Manipulation of nutrient limitations by the long-term fertilisation treatments applied in these locations allows for testing effects of nutrient availability on decomposition without the confounding effects of location and plant species composition. By comparing decomposition dynamics of litter in the different locations and treatments we can assess i) whether nutrient enrichment stimulates decomposition directly, through increasing soil nutrient availability, or indirectly, through changing leaf litter quality, ii) Whether N- or P-limited systems respond differently to enrichment with either of these elements, and iii) Whether nutrient retention during the decomposition process is diminished by external nutrient enrichment.

2. Materials and methods

This study was conducted at two mangrove-dominated locations: Twin Cays, Belize, and an impounded mangrove (Mosquito Impoundment 23) on North Hutchinson Island, Indian River Lagoon, Florida, USA (Fig. 1a). Twin Cays is a relatively pristine, peat-based, 92-ha archipelago, 12 offshore (16;50;N, 88;06;W) where it receives no terrigenous freshwater or sediment inputs (Ruetzler and Feller, 1996). Mosquito impoundment 23 is a 122-ha abandoned impoundment, located on the lagoon side of North Hutchinson Island, Indian River County, Florida, USA (27;33;N, 80;20;W). Both locations have been the focus of long-term research (e.g. (Feller et al., 2003, 2007, 2009)) with respect to eutrophication effects.

Twin Cays is underlain by deep deposits of mangrove peat, 8–12 thick (Macintyre et al., 2004). On North Hutchinson Island, in contrast, the soil is highly disturbed with little structure, composed primarily of

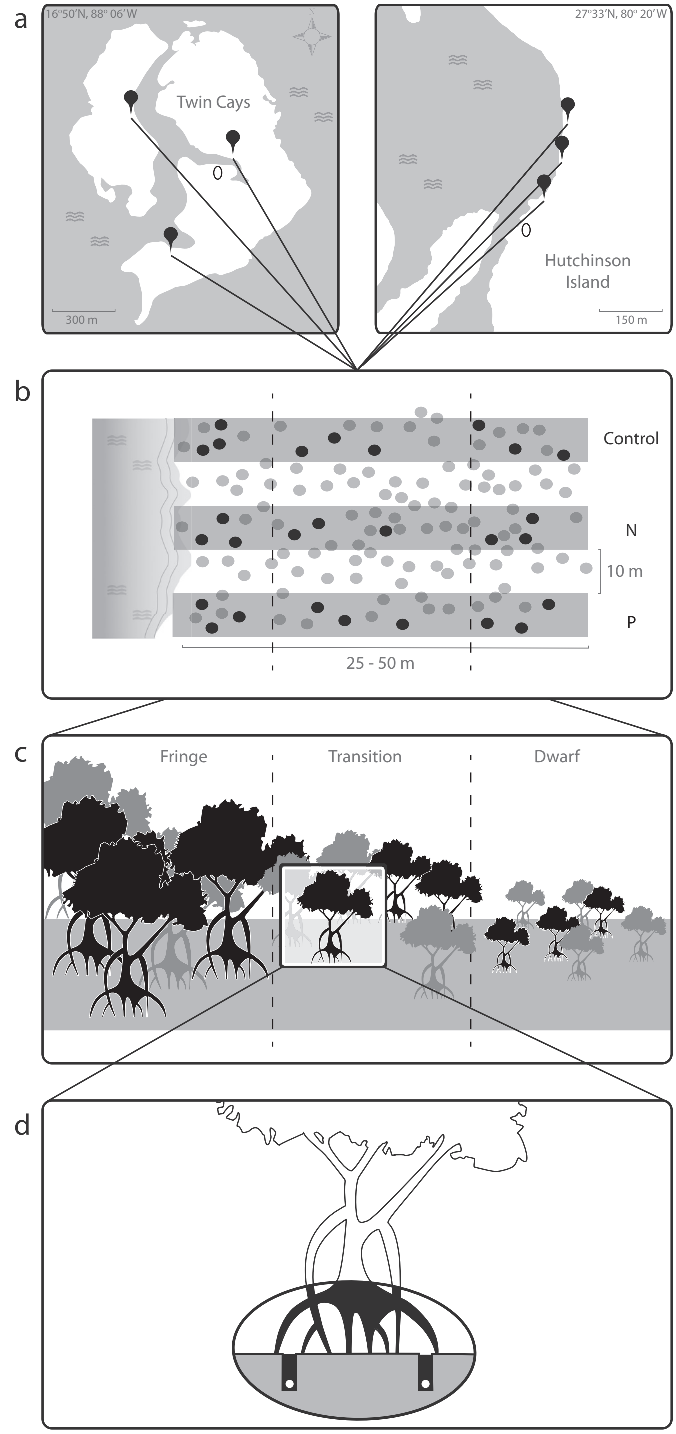

Fig. 1. a) The setup of the mangrove fertilisation experiment in Twin Cays, Belize and North Hutchinson Island, Florida, USA. Per location, three transect blocks, 2550 long, were oriented perpendicular to the shoreline. In addition, a reference plot was established at each location (open circles). b) Each transect block consisted of three parallel transects separated by 10 buffer zones against possible lateral migration of fertilisers. All transects randomly received one of three fertilisation treatments: Control, nitrogen (N) and phosphorus (P). c) Transects were subdivided into fringe, transition, and dwarf zones based on tree height. In each transect, three trees per zone were selected for treatment. d) The fertilisation was applied to specific trees by burying fertiliser-filled dialysis tubing near the roots and plugging the hole with soil substrate.

sand and shell fragments that were deposited when the impoundment was built (Feller et al., 2002, 2003).

In spite of their contrasting edaphic properties, vegetation structure is similar at both locations with a clear zonation perpendicular to the