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Replacement of native forests by conifer plantations affects fungal decomposer community structure but not litter decomposition in Atlantic island streams

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ABSTRACT

Forest change occurs worldwide, especially on islands where space is a limiting factor for human activities. The replacement of diverse native forests by tree monocultures and subsequent changes in litter input characteristics can have strong effects on stream communities and processes. Aquatic decomposers and litter decomposition can be particularly sensitive to forest change due to their dependence on terrestrial litter supply and on litter characteristics. However, studies addressing the effects of forest changes, and conifer plantations in particular, on stream litter decomposition and associated decomposers are scarce. Here, we assessed the effects of the replacement of native laurel forests in São Miguel island, Azores archipelago, by commercial conifer plantations (*Cryptomeria japonica* (L. f.) D. Don) on litter decomposition and associated fungal decomposers. Leaves of the native broadleaf tree *Ilex perado* Aiton and conifer needles were enclosed in mesh bags and incubated in three streams flowing through conifer plantations and three streams flowing through native laurel forests in winter 2015 for determination of litter decomposition rates, and aquatic hyphomycete community structure and reproductive activity (one stream per type). Aquatic hyphomycete communities' structure strongly differed between native and conifer streams as a result from differences in the total number of species recorded (higher in the native stream), species identity (only 10 species, out of 26, were common to both streams) and species evenness (higher in the native stream). These differences in communities between streams likely result from changes in litter inputs characteristics between native and conifer streams and from aquatic hyphomycetes having substrate preferences. Differences in aquatic hyphomycete communities were not accompanied by differences in litter decomposition rates between native and conifer streams, which likely results from functional redundancy between decomposer communities and suggests that community structure and function may not always be tightly coupled. Litter decomposition rates did not differ between native and conifer species because *I. perado* leaves were tough and had a tick waxy cuticle, which may have limited microbial development, as for the conifer needles. Thus, the replacement of native laurel forests by conifer plantations did not affect litter decomposition in Azorean streams likely because litter is recalcitrant and decomposition is driven by microbes. However, changes in aquatic hyphomycete communities arriving from forest change may have unpredictable effects in case of additional environmental change. Hence, to prevent unwanted effects of changes in microbial communities, a riparian buffer of native vegetation should be maintained in conifer plantations.

1. Introduction

Forest change constitutes a major environmental transformation worldwide (FAO, 2015). This is especially true for islands, where human pressure is high due to space and resources limitations (Keppel et al., 2014; Calado et al., 2016). The replacement of diverse native forests by tree monocultures is generally accompanied by decreases in litter diversity, changes in litter quantity and chemical composition (the direction and magnitude depending on species identity) and changes in the timing of litter fall (Graça et al., 2002; Inoue et al., 2012; Martínez et al., 2013). These changes can have strong impacts on stream ecosystems due to their large terrestrial-aquatic interface and strong dependence on

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terrestrial organic matter (Graça et al., 2002; Hladyz et al., 2011; Ferreira et al., 2016b).

Aquatic communities in forest streams derive most of their energy and carbon from the litter provided by the riparian vegetation (Wallace et al., 1997). Litter decomposition is thus a fundamental ecosystem process in forest streams, where it fuels aquatic communities and contributes to nutrient cycling (Wallace et al., 1997). The incorporation of litter carbon and nutrients into secondary production is driven by microbial decomposers, primarily aquatic hyphomycetes (Hieber and Gessner, 2002; Gulis and Suberkropp, 2003; Pascoal and Cássio, 2004; Cornut et al., 2010), especially on island streams, where macroinvertebrate detritivores can be rare (Benstead et al., 2009; Ferreira et al., 2016c). Since aquatic hyphomycetes have different substrate preferences as a result from different nutrient requirements and enzymatic capabilities (Arsuffi and Suberkropp, 1984, 1988; Gulis, 2001), changes in forest composition may severely affect aquatic communities' composition (Bärlocher and Graça, 2002; Ferreira et al., 2006a). However, this is not always the case with some studies finding no major differences in aquatic hyphomycete communities between streams flowing through native forests and similar streams flowing through tree plantations (Kominoski et al., 2011; Martínez et al., 2013). Additionally, community structure is not always strongly coupled with ecosystem functioning (Bärlocher and Graça, 2002; Ferreira et al., 2006a; Mckie and Malmqvist, 2009; Riipinen et al., 2009) and thus it is difficult to anticipate the effects of forest change on litter decomposition.

The effects of the replacement of native broadleaf forests by conifer plantations, in particular, on litter decomposition and associated decomposers have been rarely addressed and results are conflicting, suggesting that effects may depend on different factors such as stream characteristics, litter identity, type of conifer plantation, type of native forest and type of decomposer community involved (i.e. microbes only or microbes + macroinvertebrates) (reviewed by Ferreira et al. (2016b), Chauvet et al. (2016)).

Here, we assessed the effects of the replacement of native forests in São Miguel island, Azores archipelago, by commercial conifer plantations (*Cryptomeria japonica* (L. f.) D. Don) on native (*Ilex perado* Aiton) and conifer (*C. japonica*) litter decomposition, as a surrogate for stream functioning, and associated fungal decomposer reproductive activity and community structure. We tested the null hypothesis that forest change would not affect microbial decomposer communities' structure and litter decomposition.

2. Materials and methods

2.1. Study region

This study was done in São Miguel island, the largest (760 km^2) of the nine islands that make the Azores archipelago. This archipelago is located in the North Atlantic Ocean, in the Middle Atlantic Ridge where the North American, Eurasian and African lithospheric plates join, about 1500 km off Portugal mainland. Mean annual temperatures in the Azores range between 14 and 18 °C and mean annual precipitation between 740 and 2400 mm, depending on elevation, with most of the precipitation (70–75%) falling between October and March (Marques et al., 2008; Hernández et al., 2016).

Since the Portuguese settlement in the 15th century, human activities changed completely the island's landscape (Constância, 1963; Moreira, 1987). Due to unregulated and uncontrolled exploitation of the forest resources for wood and charcoal, and clearance for agriculture and urbanization, the original dense forests were almost completely destroyed by the beginning of the 19th century (Constância, 1963). In 1951, the forest area in São Miguel island was <6% (Dias et al., 2007a). Planting measures were undertaken to counterbalance this situation and *C. japonica*, a conifer that originates from Japan and south China and was introduced into the Azores as an ornamental tree in the mid-19th century (Albergaria, 2000), progressively became an important species once its commercial interest and its ability to adapt and resist to strong winds (a limiting factor in the Azores) were recognized (Dias et al., 2007a).

Nowadays, forests cover about 22% of the land area in the Azores (SRAM/DROTRH, 2007) with *C. japonica* plantations representing 26% of the forest area and 60% of forest plantation area, especially at elevations >400 m a.s.l. (DRRF, 2014). Native forests cover less than 10% of the total area, mostly at elevations >800 m a.s.l. (Borges et al., 2010; DRRF, 2014). Laurel forests develop in areas of high humidity and exposed to humid winds that promote an arboreal stratum composed by ombrophilous species as *I. perado*, *Laurus azorica* (Seub.) Franco, *Frangula azorica* V. Grubov and *Vaccinium cylindraceum* Sm. (Dias et al., 2007b).

2.2. Streams

The six study streams were located in the volcanic complexes of Nordeste and Fogo, in the northeast and central area of São Miguel island, respectively (Table 1). Streams were perennial, small (1st–3rd order, <1 m wide and <20 cm deep) and with the substrate composed mainly by sand, gravel and cobbles. Three streams were surrounded by native vegetation ('native streams', NAT1–NAT3) and three streams flowed through mature (45–50 years old) conifer (*C. japonica*) plantations ('conifer streams', CON1–CON3) (Table 1). Streams were not affected by any visible human activity, besides commercial forestry in the conifer streams, and thus differences in water chemistry can be attributed to forest change.

2.3. Water variables

Water temperature was recorded hourly during the litter decomposition experiment (7/8 January – 3/4 March 2015) using submerged data loggers (Hobo Pendant UA-001-08, Onset Computer Corp., MA, USA); hourly values were averaged to produce daily means (n = 55). Electrical conductivity and pH were recorded at the beginning and on each sampling date with a multiparametric field probe (CyberScan 600, Eutech Instruments, Nijkerk, the Netherlands) (n = 5). On the same occasions (n = 5), 1 L of stream water was collected in acid washed plastic bottles, transported to the laboratory cold, filtered through glass microfiber filters (47 mm diameter, 1.2 μm pore size; Whatman GF/C, GE Healthcare Europe GmbH, Little Chalfont, UK) and analyzed for phosphate, nitrate and ammonium according to Skalar methods M503-555R (Standard Method 450-P I), M461-318 (EPA 353.2) and M155-008R (EPA 350.1), respectively (Skalar, 2004).

2.4. Litter species and initial characteristics

Two litter species were selected for this study: the native broadleaf species *I. perado*, which is abundant in areas of native vegetation and is present in the surroundings of the three native streams, and the conifer species *C. japonica*, as the species used in conifer plantations. *I. perado* is an evergreen species, which precluded the collection of enough naturally abscised leaves in the short period necessary to avoid differences in leaf characteristics. Thus, *I. perado* leaves were directly collected from trees in October 2014. To reduce the variability in leaf characteristics, mature leaves of similar size and with no signs of damage or herbivory were collected from trees grown in close proximity and with similar characteristics (e.g. similar size and vitality). Although the conifer species is also evergreen, enough freshly fallen twigs were