CONTRIBUTION OF SHREDDER MACROINVERTEBRATES AND AQUATIC HYPHOMYCETES TO LITTER DECOMPOSITION IN REMOTE INSULAR STREAMS

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Ana Balibrea Escobar

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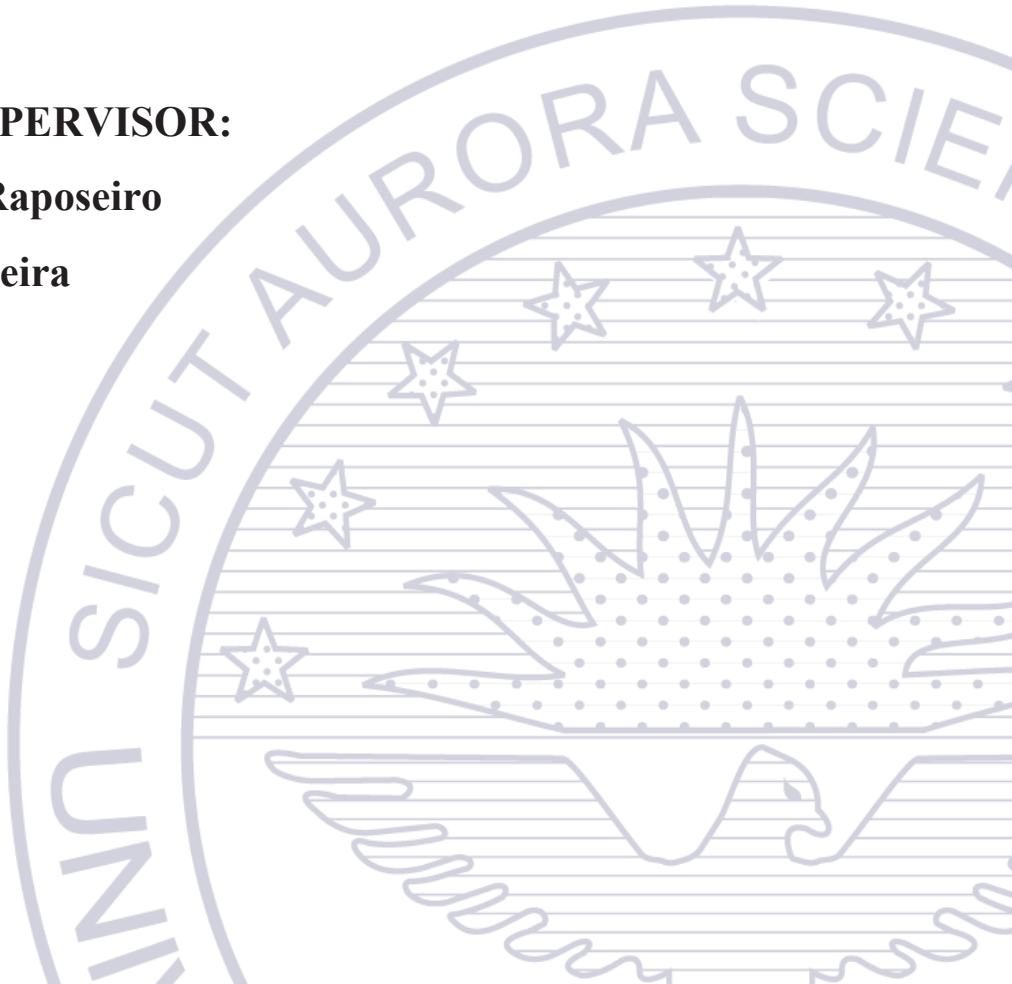

CONTRIBUIÇÃO DOS MACROINVERTEBRADOS DETRITIVOROS E HIFOMICETES AQUÁTICOS NA DECOMPOSIÇÃO DA FOLHADA EM RIBEIROS INSULARES REMOTOS

Dissertação de Mestrado submetida como requisito parcial para obtenção do grau de Mestre em Biodiversidade e Biotecnologia

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ABSTRACT

It is well known that shredders play a crucial role in organic matter processing. In oceanic freshwater systems were streams are characterized by low shredder density and richness, microbes seem to be the main litter decomposers. However, what would happen if the densities of shredders were greater? Would they contribute actively to litter decomposition? Here we try to answer these questions by evaluating the effects of shredders and aquatic hyphomycetes on litter decomposition in insular streams. Three leaf species differing in physical and chemical characteristics, *Alnus glutinosa*, *Clethra arborea* and *Cryptomeria japonica*, were enclosed in bags of coarse and fine mesh to allow and avoid macroinvertebrate access to the litter, respectively, and incubated in six streams along a gradient of *Limnephilus atlanticus* (Trichoptera) density in São Miguel island. In the presence of shredders, leaf mass loss was higher in coarse mesh bags. However, no difference in litter mass loss was found between bag types in streams with no *L. atlanticus*, despite the presence of other shredder taxa. Litter decomposition in the presence of shredder was significantly faster for *A. glutinosa* than *C. arborea* and *C. japonica.* These results suggest that when *L. atlanticus* are present at relatively high densities they may have a significant role on organic matter processing, while litter decomposition is mainly driven by microbes when *L. atlanticus* density is low, or they are absent. Moreover, litter decomposition depend on litter quality, with leaves with high nutrient concentration and low concentration of secondary compounds being more preferred by shredder and aquatic hyphomycetes.

Keywords: Litter decomposition; Shredder macroinvertebrates; Aquatic hyphomycetes; Island freshwater systems; Azores Islands

RESUMO

É bem conhecido que os trituradores desempenham um papel crucial no processamento de matéria orgânica. Nos sistemas oceânicos dulçaquícolas, onde os ribeiros são caracterizados por uma baixa densidade e riqueza de trituradores, os microrganismos (hifomicetes aquáticos) parecem ser os principais decompositores da folhada. No entanto, o que aconteceria se a densidade de trituradores fosse maior? Contribuiriam ativamente para a decomposição da folhada? Aqui tentamos responder a estas questões avaliando os efeitos dos trituradores e hifomicetes aquáticos na decomposição da folhada em ribeiros insulares. Três espécies de folhas com características físicas e químicas distintas, *Alnus glutinosa*, *Clethra arborea* e *Cryptomeria japonica*, foram colocadas em sacos de rede com malha grossa e fina para permitir e evitar a entrada de macroinvertebrados, respectivamente, e incubadas em seis ribeiros ao longo de um gradiente de *Limnephilus atlanticus* (Trichoptera) na ilha de São Miguel. Na presença de trituradores, a perda de massa foliar foi maior nos sacos de malha grossa. No entanto, nenhuma diferença significativa foi encontrada na perca de massa entre os tipos de sacos em ribeiros sem *L. atlanticus*. A decomposição da folhada na presença de trituradores foi significativamente mais rápida para *A. glutinosa* do que *C. arborea* e *C. japonica*. Os resultados mostram que, quando *L. atlanticus* está presente em densidades altas, pode ter um papel significativo no processamento de matéria orgânica, enquanto que a decomposição da folhada é principalmente mediada por microorganismos quando a densidade de *L. atlanticus* é baixa, ou estão ausentes, mesmo na presençe de outros trituradores. Além disso, a decomposição depende da qualidade da folhada, sendo as folhas com alta concentração de nutrientes e baixa concentração de compostos secundários preferidas pelos trituradores e hifomicetes aquáticos.

Palavras-chave: Decomposição de folhada; Macroinvertebrados detritívoros; Hifomicetes aquáticos; Sistemas de água doce em ilhas; Ilhas dos Açores.

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INTRODUCTION

Streams, i.e. small water courses (order ≤ 4; Strahler, 1957), represent the majority of water courses in hydrographic basins, both in number and length (Allan and Castillo, 2007). This is especially true for volcanic insular systems, where watersheds exhibit a predominantly radial drainage pattern, as streams flow away from the central peaks, the center of volcanic activity, dropping dramatically in altitude (Hughes, 2005). These streams are thus characteristically very steep with near vertical valley walls, short, narrow, shallow, and straight, and have a turbulent, torrential, and often seasonal flow regime (Malmqvist, 2002; Hughes, 2003; Smith et al., 2003). This is the case of streams in Atlantic islands that are geologically young and truly oceanic, i.e. with no physical connection to continental landmass at any time. Specifically, in the Azores archipelago there are 763 hydrographic basins draining the 2322 km^2 of land surface (Cruz and Soares, 2018; DROTH and INAG, 2001) and streams have a maximum length of 29 km (Raposeiro et al., 2013).

Many of these streams are covered by dense riparian vegetation that decreases the amount of solar energy that could be used by instream primary producers (Graça and Canhoto, 2006). Thus, allochthonous organic matter constitutes the primary source of energy and matter for aquatic food webs (Anderson and Sedell, 1979; Wallace et al., 1997; Graça, 2001; Abelho, 2001), and it is present generally in the form of leaf litter (Abelho, 2001). Litter decomposition is mainly a biological process in which microbes (mostly aquatic hyphomycetes) and macroinvertebrate shredders are the main players (Cummins et al., 1973; Hieber and Gensser, 2002; Pascoal et al., 2005; Cornut et al., 2010). Microbes colonize leaf litter soon after leaf immersion, mostly after leaching of soluble secondary compounds (Canhoto and Graça, 1996). Microbes decompose litter through respiration and incorporation of carbon into reproductive structures (spores) and biomass (Hieber and Gessner, 2002; Cornut et al., 2010). Also, aquatic hyphomycetes produce exoenzymes that depolymerize pectin, xylan and cellulose from litter leading to litter softening and the release of fine particulate organic matter (Gulis and Suberkropp, 2003). Litter softening and microbial

biomass accumulation increase litter palatability to shredders, which incorporate it into secondary production and promote the release of fine particles leading to further litter mass loss (Arsuffi and Suberkropp, 1989; Graça, 2001; Gulis et al., 2006; Graça and Cressa, 2010). Often, leaves may contain large quantities of structural polymers (e.g. cellulose and lignin) that are indigestible to shredders. Mycelia of aquatic hyphomycetes generally contain higher concentration of lipids and proteins and can be assimilated more efficiently. Thus, higher survival and growth rates were found when shredders fed on microbial-conditioned than on unconditioned leaves (Bärlocher 1985; Graça and Canhoto, 2006; Bärlocher and Sridhar, 2014). Invertebrates cannot feed exclusively on aquatic hyphomycetes mycelia that is within the leaf matrix; however, some small invertebrates can scrap mycelia from leaf surfaces (e.g. chironomidae in some tropical streams) (Wantzen and Wagner, 2006; Bärlocher and Sridhar, 2014).

It is well known that macroinvertebrate shredders play an important role in leaf decomposition in continental temperate streams (Graça, 2001; Graça and Canhoto, 2006; Pozo et al., 2011). However, oceanic island freshwater assemblages are subject to 'biogeographical filters'; strong physical barriers such as distance from continental counterparts and the open ocean, influence dispersal and species colonization (Bilton et al., 2001; Covich, 2009) resulting in less diverse biotic assemblages compared to continental systems (Hughes, 2006). In the Azores archipelago, isolation and numerous geological events and volcanic eruptions contributed to the low diversity of freshwater species (Whittaker and Fernandez-Palacios, 2007), but high level of endemism (11% of the Azorean freshwater invertebrate fauna; Raposeiro et al., 2012). In fact, only few shredder taxa have been identified in Azorean streams: *Jaera insulana* (isopod), *Limnephilus atlanticus* (caddis fly), *Dicranomyia* sp., *Tipula macaronesica* and *T. oleracea* (crane flies) (Borges et al., 2010; Raposeiro et al., 2012; Ferreira et al., 2016), and abundances are generally low (Raposeiro et al., 2013). In these, and other, oceanic island streams characterized by low shredder density or even absence, microbes seem to be the main litter decomposers (Larned, 2000; Benstead et al., 2009; Raposeiro et al., 2014; Ferreira et al., 2016). In some island streams, however, shredder density is high, and they are active players on litter decomposition (e.g. Longo and Blanco, 2014; Li and Dudgeon, 2009). In fact, several studies showed that high shredder density is a crucial driver of litter decomposition and

shredder density and decomposition rate are positively correlated (Encalada et al., 2010; Rincón and Covich 2014; Raposeiro et al., 2018).

Litter decomposition rates also depend on litter intrinsic characteristics. Soft leaves, with high concentration of nutrients (e.g. nitrogen) and low concentration of structural (e.g. lignin) and secondary compounds (e.g. polyphenols) are generally colonized and decomposed faster than tough litter, with low concentration of nutrients (Canhoto and Graça, 1995; Ferreira et al., 2016; Raposeiro et al., 2018). Shredders are especially sensitive to the concentration of secondary and structural compounds that affect litter palatability, and therefore these characteristics may be more important determining biological litter decomposition than litter nutrient concentrations (Graça and Cressa, 2010; Claeson et al., 2013; Ferreira et al., 2016). In fact, stronger differences in litter decomposition have been found among litter species in the presence of shredders than when decomposition is only microbial-driven (Pereira et al., 1998; Hieber and Gessner, 2002; Ferreira et al., 2012; Raposeiro et al., 2018).

This study evaluates litter decomposition in relation to macroinvertebrate shredder density and litter characteristics by comparing decomposition of three litter species with distinct physical and chemical characteristics (*Alnus glutinosa* (L.) Gaertn., *Clethra arborea* Aiton, and *Cryptomeria japonica* D. Don.) incubated in streams along a gradient of shredder densities (from absence to high density) in São Miguel island (Azores archipelago). The following hypotheses were tested: (1) litter decomposition is higher in the presence of shredders and is positively correlated with benthic shredder density, (2) litter decomposition varies among litter species and is higher for soft litter with high nutrient concentration, and (3) there is an interaction between shredder density and litter species on litter decomposition with (3a) shredders playing a stronger role on the decomposition of more palatable litter and (3b) differences among litter species being stronger in the presence of shredders.