

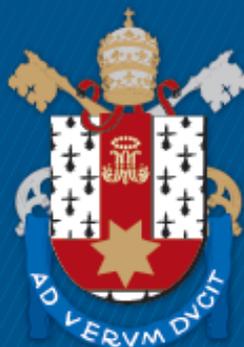
ESCOLA DE CIÊNCIAS  
PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOLOGIA  
MESTRADO EM ZOOLOGIA

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**VARIAÇÃO ALTITUDINAL DA COMUNIDADE DE INVERTEBRADOS AQUÁTICOS EM  
BROMÉLIAS DOS GÊNEROS VRIESEA GAUDICH. E AECHMEA WITTM. NA SERRA  
GERAL DO SUL DO BRASIL**

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**PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO GRANDE DO SUL**  
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## RESUMO

A Serra Geral do sul do Brasil engloba diferentes ecossistemas da Mata Atlântica, desde fragmentos remanescentes da Floresta Ombrófila Densa e Mista até os Campos de Altitude. As bromélias constituem um dos grupos com maior diversidade taxonômica, morfológica e ecológica deste bioma. Suas folhas são dispostas em roseta, e em algumas espécies, a sobreposição das folhas permite a formação de reservatórios de água e matéria orgânica, além de abrigar diversos microrganismos. No Brasil, poucos estudos descrevem a comunidade desses reservatórios, e principalmente, sua resposta a padrões ecológicos. Dessa forma, o objetivo desta pesquisa foi analisar o efeito do gradiente altitudinal sobre a comunidade de eucariotos presentes nos reservatórios de quatro espécies de *Vriesea* Gaudich. e de uma espécie de *Aechmea* (*A. gamosepala* Wittm.) que ocorrem em diferentes altitudes da Serra do sul do Brasil. As espécies/altitudes elencadas foram: *V. gigantea* (Maquiné – 20m), *V. incurvata* (Arroio Garapiá – 400m), *V. friburgensis* e *V. platynema* (Pró-Mata – 910 e 915m, respectivamente). Para *A. gamosepala*, duas altitudes de ocorrência foram selecionadas: Pró-Mata (915m) e Arroio Garapiá (400m). Foram amostrados três indivíduos de cada espécie, duas vezes para cada estação, ao longo de um ano. A água dos reservatórios foi coletada com pipeta de Pasteur e acondicionada em tubos falcon para a análise dos organismos in vivo e estimar a riqueza específica para cada uma das bromélias amostradas. Foram encontrados 45 morfoespécies nas espécies de *Vriesea*, sendo Ciliophora o filo mais representativo (53,3%), seguido de Arthropoda (28,8%), Rotifera (6,6%), Annelida, Platyhelminthes (4,4%) e Nematoda (2,2%). A riqueza específica em *V. gigantea* foi de 8,17 morfoespécies, e obteve seu pico no nível intermediário (*V. incurvata*) com uma média total de 10,79. Em maiores altitudes a riqueza diminuiu (8,83 e 8,67 morfoespécies para *V. platynema* e *V. friburgensis*, respectivamente). Para *A. gamosepala*, as bromélias de maiores altitudes obtiveram a maior riqueza fitotelmática (8,63 morfoespécies) quando comparada às de nível intermediário (8,17). O pico de riqueza específica em altitudes intermediárias é um padrão já encontrado para a avifauna, alguns artrópodes, e até microrganismos. A partir deste estudo, sugere-se que as bromélias, além de abrigarem diversos organismos em diferentes estágios de vida e funções tróficas, possuem comunidades sensíveis à variação de altitude, podendo ser modelado tanto pelo ambiente de cada nível, quanto por características *in situ* da bromélia.

Palavras-chave: Altitude; Bromélia; Fitotelmo; Invertebrados Aquáticos.

## ABSTRACT

### **“Altitudinal gradient over *Vriesea* spp. Gaudich. and *Aechmea gamosepala* Wittm. phytotelm community in a mountain range from South Brazil”**

Bromeliads are one of the groups with the greatest taxonomic, morphological and ecological diversity of the Neotropics. Its leaves are arranged in rosette, and in some species, the overlapping of the leaves allows the entrapment of water and organic matter, forming reservoirs that are habitat for various microorganisms. In Brazil, few studies describe the community of these reservoirs or their response to ecological standards. Thus, the objective of this research was to analyze the effect of the altitudinal gradient on the community of eukaryotes present in the reservoirs of four species of *Vriesea* Gaudich. and of a species of *Aechmea* (*A. gamosepala* Wittm.) that occur at different altitudes on a mountain range in Serra Geral of Southern Brazil. The species/altitudes chosen were: *V. gigantea* (Maquiné – 20m), *V. incurvata* (Arroio Garapiá – 400m), *V. friburgensis* e *V. platynema* (Pró-Mata – 910 e 915m, respectively). For *A. gamosepala*, two altitudes were selected, according to their occurrence: Garapiá River and Pró-Mata. Three individuals of each species were sampled, twice for each season, over a year. The water from the reservoirs was collected with a *Pasteur* pipette and placed in falcon tubes to analyze the organisms in vivo and to estimate the specific richness for each of the bromeliads sampled. A total of 45 morphospecies were found in *Vriesea* species, with Ciliophora being the most representative phylum (53.3%), followed by Arthropoda (28.8%), Rotifera (6.6%), Annelida, Platyhelminthes (4.4%) and Nematoda (2.2%). The specific richness in *V. gigantea* was 8.17 morphospecies, and reached its peak at the intermediate level (*V. incurvata*) with a total average of 10.79. At higher altitudes the richness decreased (8.83 and 8.67 morphospecies for *V. platynema* and *V. friburgensis*, respectively). For *A. gamosepala*, the bromeliads of higher altitudes obtained the highest phyto-elastic richness (8.63 morphospecies) when compared to the intermediate level (8.17). From this study, it is suggested that bromeliads, in addition to shelter different organisms at different life stages and trophic functions, have communities sensitive to altitude variation, being able to be modeled both by the environment, and by in situ characteristics of the bromeliad.

Key-words: Altitude; Bromeliads; Aquatic invertebrates; Phytotelm.

## APRESENTAÇÃO

O presente trabalho teve dois objetivos principais: iniciar os estudos de caracterização das comunidades que habitam as cisternas de bromélias do gênero *Vriesea* e *Aechmea* distribuídas em diferentes altitudes na Serra Geral do sul do Brasil; e no âmbito ecológico, verificar a influência do gradiente altitudinal sobre a diversidade de organismos presentes nas bromélias. Na região em que se desenvolveu o estudo (Serra Geral do Rio Grande do Sul), há numerosas cadeias de montanhas, fornecendo um contexto interessante para verificar as tendências que a biodiversidade apresenta ao longo de diferentes altitudes. De acordo com os resultados a serem apresentados nesse manuscrito, percebe-se a possível influência do gradiente altitudinal sobre a comunidade fitotelmática e, conseqüentemente, a necessidade de estudos acerca destes ambientes.

As informações obtidas durante o período de estudo foram organizadas em três capítulos. O primeiro trata-se de uma introdução geral ao tema, redigido nas regras propostas pela Associação Brasileira de Normas Técnicas (ABNT). O capítulo II é um artigo de cunho descritivo, intitulado “Altitudinal gradient over phytotelm fauna of *Vriesea* Gaudich. and *Aechmea gamosepala* Wittm. in a mountain range from South Brazil”, redigido pelas normas do Journal of Eukaryotic Microbiology. Por fim, o terceiro capítulo traz uma breve conclusão sobre os resultados obtidos neste estudo e as perspectivas futuras (redigido conforme regras da ABNT).

## CAPÍTULO I

### **Introdução Geral**

## INTRODUÇÃO GERAL

O bioma Mata Atlântica apresenta expressiva riqueza biológica devido a heterogeneidade de seus ecossistemas, permitindo a adaptação de diversas espécies a diferentes nichos ecológicos (Magurran, 1988). Embora este bioma seja mundialmente reconhecido por sua biodiversidade, dados mostram que apenas 8,5% de remanescentes florestais ainda continuam preservados no Brasil (Myers *et al.*, 2000; INPE, 2012), sendo que os ecossistemas da região sul do país figuram entre os menos protegidos e com poucas chances de terem sua área sob proteção aumentadas (Medeiros, 2004).

Bromeliaceae é uma família de monocotiledôneas que se divide em 58 gêneros e 3.172 espécies (AGP III, 2009), constituindo um dos grupos de maior diversidade morfológica, ecológica e taxonômica das plantas nativas da região Neotropical (Simão, 2016). O Brasil por sua vez, é o país com maior grau de endemismo e diversidade deste grupo, sendo *Vriesea* e *Aechmea* os dois gêneros mais abundantes da Mata Atlântica brasileira, com 166 e 136 espécies, respectivamente (Martinelli *et al.*, 2008). A ampla distribuição geográfica e o sucesso ecológico deste grupo pode ser explicado pelo epifitismo, a presença de tricomas absorventes e a fotossíntese CAM (metabolismo ácido crassuláceo), que com a abertura dos estômatos pela noite, permite transformar o dióxido de carbono atmosférico em ácido málico, substrato energético utilizado durante o dia por essas plantas (Leroy *et al.*, 2015).

Na região Neotropical, as bromélias são importantes epífitas, devido a sua abundância e a sua complexidade morfológica, onde as suas bases foliares compactas e imbricadas formam uma cisterna com capacidade de reter água. Estas cisternas podem acumular um volume de até 50 litros de água suspensa por hectare, promovendo recursos importantes para a comunidade que habita estes ambientes (Goffardi *et al.*, 2015).

O processo de colonização de tanques de bromélias parece ser complexo, envolvendo uma série de eventos interligados, como dispersão ativa e passiva, chegada e o processo de estabelecimento do organismo (Maguire, 1971). Alguns autores citam mecanismos de dispersão de organismos para corpos isolados de água, sendo eles: o vento e a chuva (passivo), o voo (ativo) e a forésia

(introdução induzida por outra espécie) (Maguire, 1963). Posteriormente compararam o processo de colonização dos fitotelmos com o de ilhas e de pântanos, dividindo os organismos em: fitotelmo-especialistas (colonização altamente seletiva) e não especialistas (colonização aleatória) (Frank and Lounibos, 1987).

Alguns estudos avaliaram o conjunto de organismos que compõem este ambiente através do sequenciamento de alto desempenho (metatranscriptômica), observando a presença de mais de 60 filões de eucariotos no fitotelmo das bromélias, incluindo o gênero *Trypanosoma*, demonstrando o quanto desconhecido é a biota desses ambientes (Dunthorn *et al.*, 2012; Simão *et al.*, 2017). Além da comunidade, pouco se sabe sobre os fatores ecológicos que podem influenciar a riqueza dos organismos que vivem nesses ambientes.

Considerando que os fitotelmos (cisternas) estão expostos a condições ambientais estressantes, como a restrição de nutrientes e déficit hídrico em períodos de estiagem, estes fatores levam ao estímulo do desenvolvimento de mecanismos de sobrevivência dos organismos para a manutenção da comunidade a longo prazo. Algumas adaptações já foram observadas em ciliados, como a formação de cistos de resistência e modificação da ciliatura oral e hábito alimentar (Foissner, 2003).

Outras respostas às flutuações ambientais dos fitotelmos é a esporulação em bactérias (Hutchison *et al.*, 2014), e a criptobiose e anidrobiose em tardígrados (Halberg *et al.*, 2013), rotíferos (Marotta *et al.*, 2010) e nematoides (Banton and Tunnacliffe, 2012). Estes processos consistem em adaptações moleculares e morfofisiológicas resultando na redução total do metabolismo em períodos de estiagem, podendo retornar à atividade após a hidratação (Clegg, 2001).

Estudos sobre os organismos que habitam os fitotelmos das bromélias são geralmente focados em táxons específicos, como: arqueas (Martinson *et al.* 2010; Brandt *et al.*, 2015), algas (Sophia *et al.*, 2004; Brouard *et al.*, 2011), fungos (Ruivo *et al.*, 2005; Araujo *et al.*, 2012; Safar *et al.*, 2013), ciliados (Foissner *et al.*, 2003; Dunthorn *et al.*, 2012; Duran-Ramirez *et al.*, 2015), crustáceos (Jocque *et al.*, 2013) e artrópodes (Bacigalupo *et al.*, 2006; Marques

*et al.*, 2012). Ainda é relatada relações mutualísticas entre bromélias e formigas, aranhas, moluscos e rãs (Benzing, 2000; Leroy *et al.*, 2015).

Mesmo em baixas densidades, alguns vetores de doenças de interesse de saúde pública foram relatados em associação com bromélias, como os gêneros *Aedes*, *Anopheles* e *Culex* (Frank and Lounibus, 2009; Marques *et al.*, 2012; Muller and Marcondes, 2007). Também registrou-se a associação de *Trypanosoma cruzi* em barbeiros, agentes transmissores da doença de chagas (Bacigalupo *et al.*, 2006). Estes organismos, em conjunto, formam uma cadeia trófica, abrangendo diversas funções ecológicas tais como produção primária, predação, competição e decomposição (Kitching, 2000).

O ambiente formado pelo fitotelmo das bromélias pode ser complexo e acabar fornecendo uma variedade de compartimentos e gradientes ecológicos (Richardson *et al.*, 1999). Este microambiente não só beneficia a comunidade de organismos aquáticos e a bromélia (que se beneficia com os nutrientes fornecidos pela decomposição), como também fornece abrigo, proteção e fontes de água e alimento para aves e mamíferos. Desta forma, os fitotelmos das bromélias contribuem significativamente para a ampliação da diversidade biológica nos ecossistemas que estão inseridos, expandindo a disponibilidade de recursos e habitats (Benzing, 2000).

No sul do Brasil, grande parte dos remanescentes florestais da Mata Atlântica estão localizados nas áreas de encosta da cadeia de montanhas da Serra Geral, poupados por serem áreas íngremes e de difícil acesso (Kageyama and Gandara, 2000). Esses remanescentes têm um papel importante para conservação como corredores ecológicos, proporcionando o fluxo gênico entre populações isoladas (Silva and Tabarelli, 2000). Aliado à grande diversidade do bioma mata atlântica, as montanhas podem fornecer um contexto interessante para avaliar como as comunidades de organismos se distribuem em um gradiente altitudinal.

Em montanhas tropicais úmidas, a riqueza de espécies geralmente diminui com o aumento da altitude, sendo os principais fatores envolvidos: redução do habitat, da pressão atmosférica, da temperatura do ar, o aumento da radiação solar e outros fatores associados (Korner, 2007; McCain, 2009; McCain, 2010).

Apesar destas diferenças serem perceptíveis para muitos grupos de animais, apenas Richardson (1999) investigou como este padrão atua sobre a comunidade fitotelmática, encontrando picos de riqueza específica em altitudes intermediárias, e um decréscimo monotônico da diversidade à medida que aumenta a altitude.

O EDG (*Elevational Diversity Gradient*) é um padrão ecológico utilizado para avaliar tendências da biodiversidade em diferentes altitudes. Rahbek (1995) apresentou uma revisão literária com os padrões da riqueza de espécies ao longo de gradientes altitudinais, e em metade dos estudos detectaram um pico do número de espécies em altitudes intermediárias. Dentre eles, destaca-se comunidades vegetais (Whittaker, 1960; Janzen, 1973; Whittaker and Niering, 1975), de insetos (McCoy, 1990; Gutiérrez, 1997; Fleishman *et al.*, 1998) e aves (Rahbek, 1997). Em geral, estudos com gradientes altitudinais são aplicados para táxons específicos, entretanto, a comunidade que habita o fitotelmo das bromélias pode ser muito diversa, abrigando diversos táxons com diferentes funcionalidades.

O Brasil, sendo o país com maior grau de endemismo e diversidade de bromélias, possui poucos estudos acerca da fauna acompanhante dessas plantas. Além do caráter descritivo, pouco se sabe sobre como os fatores ecológicos influenciam esses ambientes. A bromélia, como ser vivo, ocupa a perspectiva de um ecossistema, com uma comunidade estabelecida, interagindo com seus recursos bióticos e abióticos. Sabe-se que as bromélias, comparadas a outras espécies terrestres de plantas, se aperfeiçoaram na assimilação de diferentes formas orgânicas e inorgânicas de nitrogênio (Benzing, 1970). Por serem epífitas, suas fontes são a decomposição da matéria orgânica, as chuvas e principalmente, o nitrogênio oriundo da fauna associada, enfatizando a ligação evolutiva com a comunidade fitotelmática (Brighigna *et al.*, 1992; Stewart *et al.*, 1995).

O conhecimento acerca da diversidade de espécies é fundamental para descrição e para melhorar o gerenciamento, conservação e recuperação de uma área (Melo, 2008). Dessa forma, as bromélias se tornam potenciais ferramentas para a conservação da Mata Atlântica por sua distribuição restritamente

neotropical e por abrigar uma diversidade ainda desconhecida e sensível às mudanças ambientais. Considerando a urgência de medidas para proteção dos remanescentes florestais, acredita-se que estudos com estas plantas e com a biodiversidade que a acompanha consiga contribuir para a preservação dos ecossistemas que estão inseridas.

Dessa forma, o presente estudo têm como objetivos fornecer dados sobre a composição da comunidade fitotelmática de quatro espécies de bromélias do gênero *Vriesea* Gaudich. e de *Aechmea gamosepala* Wittm. distribuídas ao longo de um gradiente de altitude na Serra Geral do sul do Brasil, e verificar a influência deste gradiente altitudinal sobre a riqueza de organismos presentes nas bromélias. Além disso, a variação sazonal da comunidade presente em cada bromélia também será analisada, bem como a similaridade na composição da comunidade das bromélias do gênero *Vriesea* spp.

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## CAPÍTULO II

### **“Altitudinal gradient over species richness of tank bromeliads fauna in a mountain range from South Brazil”**

Malfatti, E. and Utz, L. R. P.

Artigo redigido nas normas da revista Journal of Eukaryotic Microbiology, exceto na disposição das figuras e tabelas mantidas no corpo do texto a fim de facilitar a leitura.

**“Altitudinal gradient over *Vriesea* spp. Gaudich. and *Aechmea gamosepala* Wittm. phytotelm community in a mountain range from South Brazil”**

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Abstract

Serra Geral in southern Brazil encompasses different ecosystems of the Atlantic Forest, from remnants of the Dense and Mixed Ombrophilous Forest to the Altitude Fields. Bromeliads are one of the groups with the greatest taxonomic, morphological and ecological diversity of this biome. Its leaves are arranged in rosette, and in some species, the overlapping of the leaves allows the entrapment of water and organic matter forming reservoirs, and creating a habitat for various microorganisms. In Brazil, few studies describe the community of these reservoirs, and mainly, their response to ecological standards. Thus, the objective of this research was to analyze the effect of the altitudinal gradient on the community of eukaryotes present in the reservoirs of four species of *Vriesea* Gaudich. and of a species of *Aechmea* (*A. gamosepala* Wittm.) that occur at different altitudes on a mountain range in Serra Geral, southern Brazil. The species/altitudes chosen were: *V. gigantea* (Maquiné – 20m), *V. incurvata* (Arroio Garapiá – 400m), *V. friburgensis* e *V. platynema* (Pró-Mata – 910 e 915m, respectively). For *A. gamosepala*, two altitudes were selected, according to their occurrence: Garapiá River and Pró-Mata. Three individuals of each species were sampled, twice for each season, over a year. The water from the reservoirs was collected with a *Pasteur* pipette and placed in falcon tubes to analyze the organisms in vivo and to estimate the specific richness for each of the bromeliads sampled. A total of 45 morphospecies were found in *Vriesea* species, with Ciliophora being the most representative phylum (53.3%), followed by Arthropoda (28.8%), Rotifera (6.6%), Annelida, Platyhelminthes (4.4%) and Nematoda (2.2%). The specific richness in *V. gigantea* was 8.17 morphospecies, and reached its peak at the intermediate level (*V. incurvata*) with a total average of 10.79. At higher altitudes the richness decreased (8.83 and 8.67 morphospecies for *V. platynema* and *V. friburgensis*, respectively). For *A. gamosepala*, the bromeliads of higher altitudes obtained the highest phyto-elastic richness (8.63 morphospecies) when compared to the intermediate level (8.17). The specific richness peak at intermediate altitudes is a pattern already found for avifauna, some arthropods, and even microorganisms. From this study, it is suggested that bromeliads, in addition to

shelter different organisms at different life stages and trophic functions, have communities sensitive to altitude variation, being able to be modeled both by the environment of each level and by in situ characteristics of the bromeliad.

Key-Words: Bromeliad; Phytotelm; Altitude; Aquatic invertebrates.

## INTRODUCTION

Mountain ranges provide interesting environments for studying how the diversity of organisms varies at different altitudes. In southern Brazil, most remnants of the Atlantic Forest are located in the hillside areas of the Serra Geral mountain range, saved by acclivity and access difficulty (Kageyama and Gandara, 2000). These remnants include one of the largest biodiversity hotspots in the world (Myers *et al.*, 2000). In Brazil, 8% of these remnants are preserved and, the southern ecosystems have few chances to be protected (Medeiros *et al.*, 2004).

Bromeliads are one of the most important groups of plants in this biome due to their strictly Neotropical distribution, their morphological complexity and epiphytic habit. Their leaves are arranged in rosetes, and in its bases, the accumulation of water and organic matter, promotes an environment for several organisms (Goffardi, Jang, and Haroon, 2015), emphasizing the importance of these plants in the expansion of biological diversity (Tews *et al.*, 2004). In terms of occurrence of bromeliads, Brazil is the country with the highest degree of endemism and diversity of this group (Martinelli *et al.*, 2008).

The process of colonization of bromeliad tanks seems to be complex, involving a series of interconnected events, such as active and passive dispersion, arrival, and the process of establishment of the organisms (Maguire, 1971). Phytotelms are also exposed to stressful conditions, such as nutrient and water restriction during dry seasons, promoting survival mechanisms for long-term maintenance of the community (Foissner, 2003; Hutchison *et al.*, 2014; Halberg *et al.*, 2013).

Foissner (2003) and Dunthorn *et al.* (2012) conducted a study on the diversity and degree of endemism of ciliates in Neotropical phytotelms, verifying at least 28 endemic species to these environments. Some adaptations of the ciliates group to the environmental fluctuations of these habitats have already been observed, such as the formation of resistance cysts and the modification of body size and oral ciliature, promoting a flexibility in eating habits. Most tank ciliates are bacteriophagous, but some groups feed on a variety of protists and small metazoans (Foissner *et al.*, 2003).

Some studies investigated the community that inhabits the phytotelm of different bromeliad species through metabarcoding, identifying more than 60 taxa of different groups, including archaea, bacteria and a diverse eukaryotic community (Dunthorn *et al.*, 2012, Simão *et al.*, 2017). Studies on the organisms that inhabit the phytotelm of bromeliads are generally focused on specific taxa such as archaea (Martinson *et al.*, 2010; Brandt *et al.*, 2015), algae (Sophia *et al.*, 2004; Brouard *et al.*, 2011), fungi (Ruivo *et al.*, 2005, Araujo *et al.*, 2012), ciliates (Foissner *et al.*, 2003, Dunthorn *et al.*, 2012), crustaceans (Jocque *et al.*, 2013), and arthropods (Bacigalupo *et al.*, 2006; Marques *et al.*,

2012). Moreover, mutualistic relationships have also been reported between bromeliads and ants, spiders, mollusks, and frogs (Benzing, 2000; Leroy *et al.*, 2015).

In tropical humid mountains, species richness generally decreases with increasing altitude, with the main factors involving: habitat reduction, atmospheric pressure, air temperature, increased solar radiation, and other associated factors (Korner, 2007; McCain, 2009; McCain, 2010). Although these differences are noticeable for many groups (Rahbeck, 1995), only Richardson (1999) investigate altitudinal differences in bromeliad phytotelmata communities on a mountain range in Puerto Rico. In the bromeliad ecosystem, there was a tendency of decreasing abundance with increasing altitude, and a peak of specific richness in the mid-elevation.

Therefore, the aim of this study was to investigate the phytotelm community of four *Vriesea* Gaudich. species and of *Aechmea gamosepala* Wittm. distributed along a mountain range in Serra Geral, southern Brazil, and to identify the influence of a height gradient on the species richness of the community. The relative abundance of organisms, the similarity between the bromeliads communities and their seasonal variance were also analyzed.

## MATERIAL AND METHODS

**Study area:** The study was conducted along an altitudinal gradient of Atlantic forest areas located in the southern part of a mountain range, in Rio Grande do Sul, Brazil (29° 39' 41" S and 50°12' 59" W, 29° 29' 46" S and 50° 20' 00" W) between October 2017 and September 2018. Three sampling sites were selected (Figure 1) according to the bromeliads distribution along the altitudinal gradient: Maquiné (~20m); Garapiá River (~400m) and Pró-Mata (~910m). A total of eight sampling campaigns were carried out, two in each season: spring, summer, fall, and winter.

Maquiné city (29°35'S 50°16'W), the sampling point at sea level, is located in the northeast region of Rio Grande do Sul, in the Maquiné river basin. The catchment area of the Maquiné river has approximately 546 km<sup>2</sup> and is inserted in a transition area between the slopes of Serra Geral and the coastal plain, whose altitudes decrease rapidly. This feature determines a landscape with well defined plains and mountains along the entire Maquiné river valley (Gerhardt *et al.*, 2000). The Garapia River (29° 30" S 50°14'), the point at intermediate altitude, occurs in a trail inside the valley and is less disturbed. It presents an initial stretch along an access route to a waterfall, within a forest with secondary vegetation, currently little impacted. The high altitude sampling site was located the CPCN – Pró-Mata (29° 29' S 50° 21'), in São Francisco de Paula. This area is constituted by a mosaic of ecosystems, such as the Atlantic and Araucária forest, and the top fields of the mountain range, including expressive biological diversity. According to Köppen's classification, the climate in the study region is framed as mesothermic, with undefined dry season and with hot summer (Cfa), and average annual precipitation in the basin corresponds to 1608 mm.

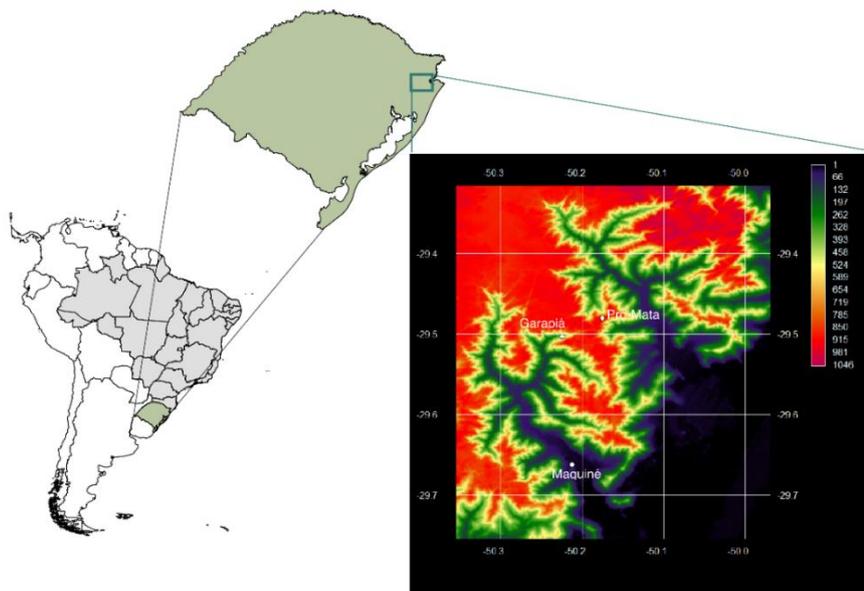


Figure 1. Altitudinal gradient of the study area, in a mountain range from Serra Geral, Rio Grande do Sul, Brazil.

The study area is framed in the Neotropical Phytogeographic Region (Cabrera and Willink, 1973). The global scale biogeographic classification developed by the WWF-World Wild Life Fund (Olson *et al.*, 2001) classifies the rainforest that reaches the CPCN-Pró-Mata from its slopes in Serra do Mar coastal forest. This biogeographic unit comprises the coastal rain forests that cover the mountain ranges, from Rio de Janeiro to Rio Grande do Sul, including lowland, submontana, montana and altomontana formations, subject to high rainfall. With a high precipitation, we can assure a more efficient sample, once we depend of tank bromeliads filled with water.

**Bromeliad species:** In each sampling site at least one species of bromeliad was sampled per height: For *Vrisea* species, *Vrisea gigantea* Gaudich phytotelm water was sampled in Maquiné, *Vrisea incurvata* Gaudich. in Garapiá River, and *Vrisea platynema* Gaudich. and *Vrisea friburgensis* Gaudich in Pró-Mata. *Aechmea gamosepala* Wittm. was sampled in Garapiá River and Pró-Mata.

**Sampling standardization:** For each bromeliad species, three individuals were sampled randomly in every campaign. Fifteen milliliters of the phytotelm water were collected using a sterile pipette and placed in Falcon tubes. Eight milliliters of each sample were maintained refrigerated (~6-10 °C) for qualitative analysis, and 7ml were fixed with acid Lugol (10%), for abundance estimation. For the quantitative analyses, one milliliter of each fixed samples was analyzed using a Sedgwick-Rafter counting cell chamber. Three replicates of the quantitative samples were counted and the average of organisms present in each bromeliad sampled was obtained.

**Taxa determination:** The ciliate assemblage, as well as the rest of the eukaryotic community were observed *in vivo* using an optic microscope (acho que tem que colocar a marca aqui), and taxonomic determination was performed using specific literature (Patterson, 2003), and other auxiliary articles (Pinho, 2008; Foissner *et al.*, 2003; Foissner *et al.*, 2003b; Brinkhurst, and Wetzel, 1984) to characterize the ciliates and other eukaryotic groups present in the phytotelmata.

**Data analysis:** Species richness variation along the altitudinal gradient was obtained by the mean value of the three replicates, and was represented in boxplots. The relative abundance was estimated by the mean value of each morphospecies occurrence, and for each season of the year. The qualitative data obtained for each bromeliad was analyzed using the Jaccard similarity index. The package “Vegan”, function “vegdist” from RStudio® software was used to calculate Jaccard index and draw a cladogram to analyze similarities among the studied bromeliads. ANOVA variance analysis was performed to access statistically significant differences in species richness among different altitudes.

## RESULTS

### *Vriesea* spp. community composition

A total of 144 *in vivo* samples were analyzed, 24 for each species. In the phytotelmata of species of *Vriesea* a total of 45 morphospecies were found distributed among six groups. The most representative phyla were: Ciliophora (24), Arthropoda (13), Rotifera (3), Annelida (2), Plathelmyntes (2), and Nematoda (1). Table 1 shows different morphospecies found in the sampled *Vriesea* species at different altitudes.

Table 1. Eukaryotic community assemblage found in four species of *Vriesea* distributed along a mountain range in Serra Geral, Brazil.

Morphospecies	<i>V. platynema</i> (915m)	<i>V. friburgensis</i> (910m)	<i>V. incurvata</i> (400m)	<i>V. gigantea</i> (20m)
<b>Rotifera</b>				
Philodinidae I	*	*	*	*
Philodinidae II	*	*	*	*
Philodinidae III	-	-	*	-
<b>Ciliophora</b>				
<i>Lambornella trichoglossa</i>	*	*	*	*
<i>Paramecium caudatum</i>	*	*	*	*
<i>Glaucoma</i> sp.	*	*	*	*
<i>Colpoda</i> sp.	*	*	*	*
<i>Tetrahymena</i> sp.	*	*	*	*
Unidentified ciliate (Tetrahymenidae)	*	*	-	*
<i>Halteria</i> sp.	*	*	*	*
<i>Stentor</i> sp.	*	-	-	-
<i>Rabdostyla</i> sp.	*	*	*	*
<i>Euplotes</i> sp.	*	*	*	*
<i>Vorticella</i> sp.	*	*	*	-
<i>Loxodes</i> sp.	*	*	*	*
<i>Discomorphella</i> sp.	*	-	*	-
<i>Pleuronema</i> sp.	*	-	-	-
<i>Lagemophrys</i> sp.	-	-	*	-
<i>Trochilia</i> sp.	-	-	*	*
<i>Holostica</i> sp.	-	-	-	*
<i>Spirostomum</i> sp.	-	-	-	*
<i>Metopus</i> sp.	-	-	-	*
Hipotrichia	*	*	*	*
Not identified II ( <i>Colpoda</i> sp.)	-	-	-	-
Not identified III	-	-	*	-
Not identified IV	-	-	*	-
<b>Arthropoda</b>				
<i>Atheyella fuhrmani</i> (Copepode)	*	*	*	-
Scirtidae larvae (Coleoptera)	*	*	*	*
Culicidae larvae I (Diptera)	*	*	*	*

Culicidae larvae II (Diptera)	*	*	*	*
Chironomidae larvae I (Diptera)	*	*	*	*
Chironomidae larvae II (Diptera)	*	*	*	*
Ceratopogonidae larvae I (Diptera)	-	-	*	*
Ceratopogonidae larvae II (Diptera)	-	-	-	*
Thaumalidae larvae (Diptera)	-	-	*	-
Psychodidae larvae (Diptera)	-	-	-	*
Acari	*	*	*	*
<i>Elpidium bromeliarum</i> (Ostracode)	*	*	*	*
<i>Elpidium</i> sp. II (Ostracode)	*	*	*	*
<b>Annelida</b>				
<i>Dero</i> sp.	*	*	*	*
Oligochaeta II	*	-	*	-
<b>Nematoda</b>				
Nematode	*	*	*	*
<b>Platyhelminthes</b>				
Flatworm I	-	*	*	*
Flatworm II	*	*	*	*

Author, 2019.

At a high altitude, a total of 30 and 28 species were founded in *V. platynema* and *V. friburgensis*, respectively. At sea level and in middle altitude, 32 morphospecies were observed in *V. gigantea*, and 35 in *V. incurvata* (Figure 2).

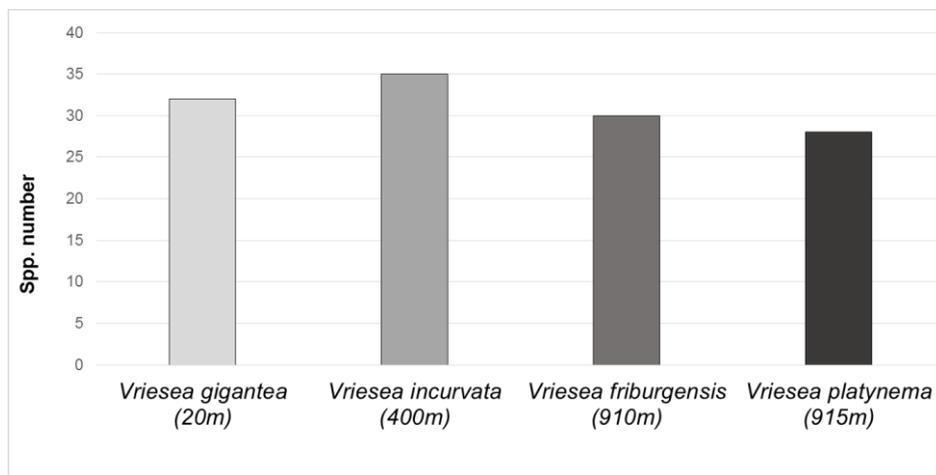


Figure 2. Phytotelm community species richness found in species of *Vriesea* distributed along a mountain range in Serra Geral, Rio Grande do Sul (BR) based on data collected during the study period (Oct./2017-Sept./2018).

The richness variation of the community, and the most representative groups in the phytotelms of each species of *Vriesea* are shown in Figure 3. The boxplots contain a dataset from samples collected between October 2017 and September 2018.

ANOVA was performed to identify significative differences between the altitude and the specific richness of the total community, as well as the most

representative groups. No statistically significant difference was observed among altitudes for the total community ( $p = 0,98$ ) ciliate ( $p = 0,426$ ), and arthropod ( $p = 0,136$ ) communities. The rotifer community, in contrast, was the only group that showed statistically significant difference among altitudes. ( $p = 0,021$ ).

In the lower altitude, the community in phytotelmata of *V. gigantea* shows an average of 8.17 morphospecies for each phytotelm sampled. In *V. incurvata* the phytotelm community presented an average of 10.79 morphospecies, showing a tendency to increase diversity in the middle altitude. The specific richness in species of *Vriesea* in high altitudes are very similar, with an average of 8.83 morphospecies found in *V. platynema*, and 8.67 observed in *V. friburgensis*. These numbers reveal a tendency to decrease the richness of species in high altitudes.

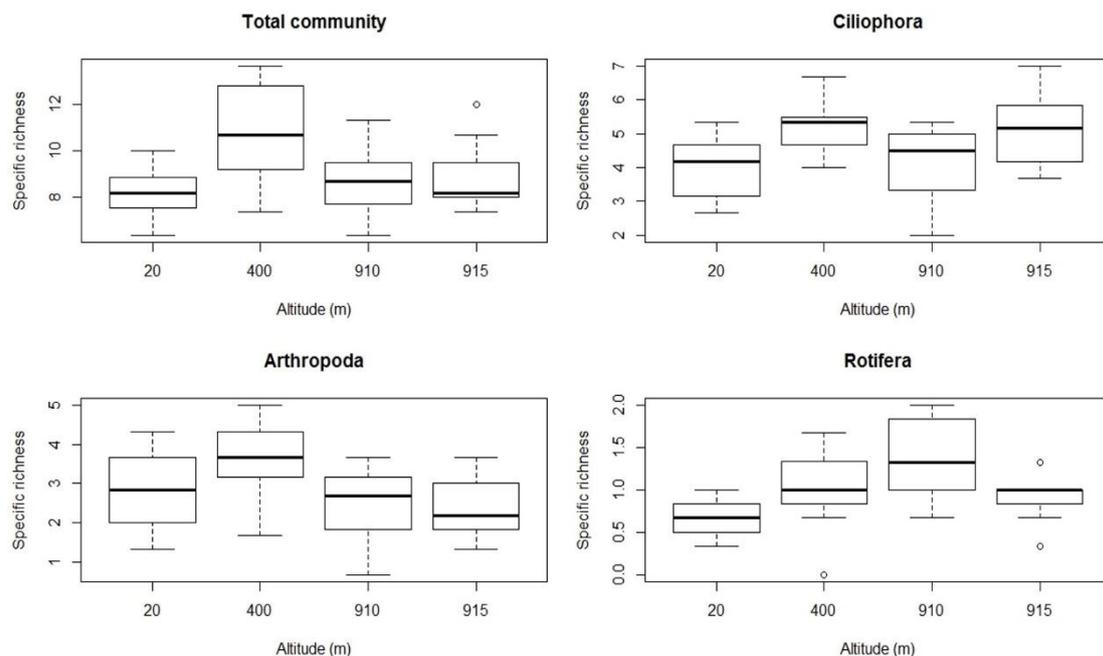


Figure 3. Richness average of phytotelmata community among species of *Vriesea* at different altitudes: *V. gigantea* at sea level (20m); *V. incurvata* at intermediate altitude (400m); *V. platynema* and *V. friburgensis* at high altitudes (>900m). The richness average of the most representative groups are in the main title of the graphics.

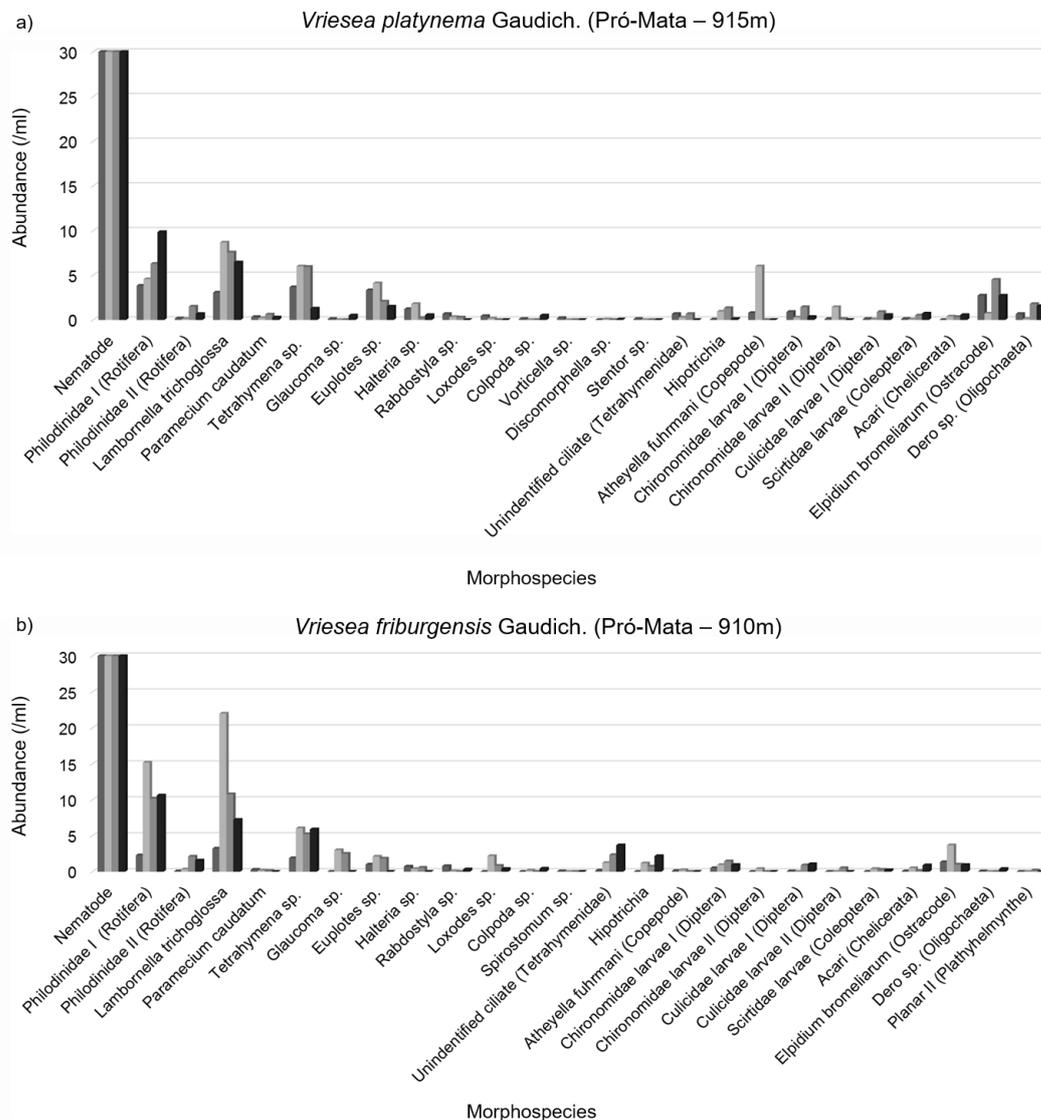
The richness variation of the most representative groups (those that presented  $\leq 3$  morphospecies) showed different patterns of occurrence among the sampled altitudes as could be seen in Figure 2. For the ciliate assemblage, the middle and higher altitude were the most representative occurrence, with both *V. platynema* and *V. incurvata* showing similar richness, with 5.13 and 5.21 morphospecies, respectively.

The arthropod richness in the phytotelmata community showed highest values in the middle altitude, with an average of 3.63 morphospecies for *V. incurvata*.

*gigantea* at sea level presented a community with 2.83 spp., while *V. platynema* and *V. friburgensis*, at high altitude presented 2.38 and 2.46 spp respectively. In relation to other eukaryotic groups, although the three different morphospecies of rotifers occur in *V. incurvata*, an annual average of presence of the morphospecies of this group shows a long established occurrence of them in *V. friburgensis*.

#### Seasonal variation of phytotelmata community in different species of *Vriesea*

As shown in Figure 4, the occurrence and abundance of each morphospecies present in *Vriesea* and their seasonal variance were estimated by the mean of individuals present in each bromeliad. There are similarities and differences in patterns of occurrence. First, we consider a maximum value for nematodes abundance (30) due to their high presence in the samples. In this way, the histogram graphics and the occurrence of other rare organisms can be clear understood.



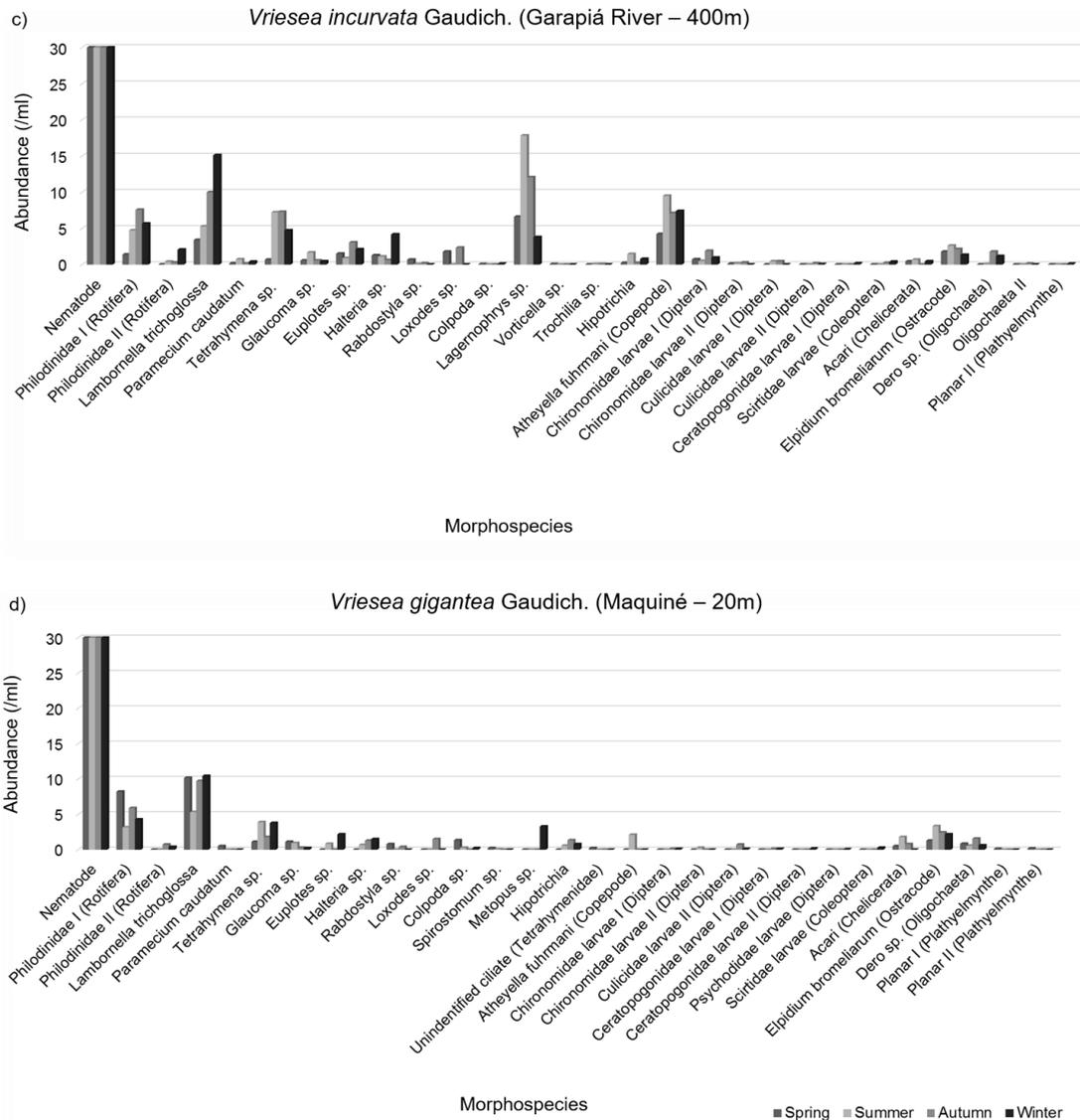


Figure 4. Seasonal variation of *Vriesea* phytotelmata community. The ciliate assemblage is expressed mostly at genus level, while the other groups are specified inside the parenthesis. a) *V. platynema* (~915m); b) *V. friburgensis* (~910m); c) *V. incurvata* (~400m) and d) *V. gigantea* (~20m). The colours of each season are represented by a sequence from spring, summer, autumn, and winter.

For all *Vriesea* species, there was a high dominance of Nematodes and the rotifer morphospecies Philodinidae I, a very common organism in the phytotelm community. We also detected an occurrence of another rotifer morphospecies, that was named Philodinidae II. This morphospecies presented morphological differences and a different swimming mode when compared with Philodinidae I. Philodinidae I showed an increasing population in *V. gigantea* during the spring (8.22 ind./ml.), in *V. incurvata* during the autumn (7.56 ind./ml), and in *V. friburgensis* during summer (15.17 ind./ml). *V. platynema* showed a peak of Philodinidae I population during the winter season (9.83 ind./ml).

At all altitudes there was a high occurrence of *Lambornella trichoglossa* in *Vriesea* species sampled. A total 6.43 individuals/ml were found in *V.*

*platynema*, 10.81 in *V. friburgensis*, 8.45 in *V. incurvata*, and 10.44 individuals in *V. gigantea*. *Tetrahymena* sp. was also a common ciliate morphospecies observed in all *Vriesea* species, as well as *Glaucoma* sp., *Loxodes* sp., *Rabdostyla* sp., *Colpoda* sp., *Halteria* sp., *Euplotes* sp., *Paramecium caudatum* and hypotrich ciliates.

On the other hand, some ciliates morphospecies had host specific occurrence. For example, *Stentor* sp. and *Discomorphella* sp. occurred only in *V. platynema*, while *Trochilia* sp. and *Metopus* sp. were present in *V. incurvata* and *V. gigantea* respectively. It is interesting to notice that *Metopus* sp. was observed only during the winter, with a population of 3.28 ind./ml. The ciliate genus *Lagenophrys*, which lives as epibiont on aquatic invertebrates, was the most abundant ciliate in *V. incurvata*. In this bromeliad species, *Lagenophrys* sp was found attached to ostracod shells, with an infestation rate of more than one individual per host. This would explain their high occurrence in this bromeliad species. *Lagenophrys* population showed an increasing peak during the summer season, with an average of 17.83 ind./ml. *Elpidium bromeliarum*, host of *Lagenophrys* sp., also shown a highest peak in the summer (2.61 ind./ml).

*Vorticella*, *Spirostomum*, and a giant unidentified tetrahymenid ciliate (~600 micrometers) are some examples of ciliate genera found at two different altitudes. *Vorticella* was found in *V. platynema* and *V. incurvata* (at high and middle altitudes), while *Stentor* occurs in *V. friburgensis* and *V. gigantea* (at high and sea level altitudes). The giant tetrahymenid ciliate was observed in bromeliad species collected in Pró-Mata, and in *V. gigantea* at sea level. The highest occurrence of this ciliate was observed in *V. platynema* and in *V. friburgensis*. In *V. platynema* the tetrahymenid ciliate was present in all seasons, with exception of the winter, while in *V. friburgensis* it occurred in all seasons with a population peak during the winter (3.67 ind./ml). In *V. gigantea* this ciliate was found only during spring and in low numbers (0.22 ind./ml).

The arthropod community was also diverse and showed interesting patterns in the different *Vriesea* species. Chironomidae larvae (Diptera, Insecta) are well-known as top predators in phytotelm communities, which explains the occurrence of two morphospecies in all sampled *Vriesea* species. Not only they occur in all species and altitude sampled, but their frequency in the samples were also relevant, due to their size and population density. In addition, two species of mosquito larvae in the Culicidae family, were present in *Vriesea* phytotelms. Their highest abundance was observed in *V. friburgensis*, with a total average of 0.50 and 0.10 ind./ml for morphospecies I and II respectively). Other families in the Diptera order occurred during the winter. For example, two different morphospecies of Certapogonidae larvae were found in *V. incurvata* (morphospecies I – 0.04 ind./ml) and in *V. gigantea* (morphospecies I – 0.11 and morphospecies II – 0.17 ind./ml). A Psychodidae larvae was also found in the tanks of *V. gigantea* at an abundance of 0.06 ind./ml. Scirtidae larvae morphospecies occurred in all *Vriesea* species, with highest abundance observed in *V. gigantea* (0.28 ind./ml). Although there was low abundance comparing to other organisms, this coleopteran larvae was present in phytotelmata in all seasons sampled.

The harpacticoid copepod *Atheyella fuhrmanii* was very abundant in the phytotelmata of all *Vriesea* species. At high altitudes, we found a large population of this copepod species, with a peak of 6 ind./ml in *V. platynema*, and 0.22 ind./ml in *V. friburgensis*, during the summer. In *V. incurvata*, *A. fuhrmanii* presented a peak of abundance (9.5 ind./ml) during summer, with an average range of 4.22 individuals/ml in the spring. *Elpidium bromeliarum*, an ostracode species commonly found in phytotelmata of bromeliads, occurred in high abundance in *V. gigantea* and *V. platynema* (2.67 and 2.30 ind./ml, respectively). Their shells are used as substrate for attachment by peritrich ciliates, such as *Lagenophrys*, *Rabdostyla*, and *Vorticella*. The presence of this epibiotic relationship was observed in the sampled bromeliads. A morphospecies of a mite was also observed to host *Rabdostyla* ciliates. This mite occurred in all *Vriesea* species, with highest abundance observed in *V. gigantea* (0.79 ind./ml).

Two other groups also have an impressive abundance in the phytotelmata communities sampled. One of them was the phylum Annelida represented by two morphospecies of Oligochaeta (*Dero* sp. and Oligochaeta II). Populations of *Dero* sp. were very abundant at all seasons in *V. platynema* and *V. gigantea*, with a total average of 1.03 and 0.89 ind./ml, respectively. Oligochaeta II occurred only in *V. incurvata* during the autumn, with an average of 0.11 ind./ml. The phylum Platyhelminthes was represented by a morphospecies of flatworm (Flatworm II). This morphospecies was found in *V. friburgensis* during autumn (0.17 ind./ml) and in *V. incurvata* during spring (0.11 ind./ml). The total average of all morphospecies present in each bromeliad can be seen in Appendix I-IV, and it was used to estimate similarity in the composition of the phytotelm communities of different *Vriesea* species.

#### Similarity in the phytotelm community composition of species of *Vriesea*

The cladogram with the Jaccard-index values of similarity between the *Vriesea* spp. Bromeliads is shown in Figure 5.

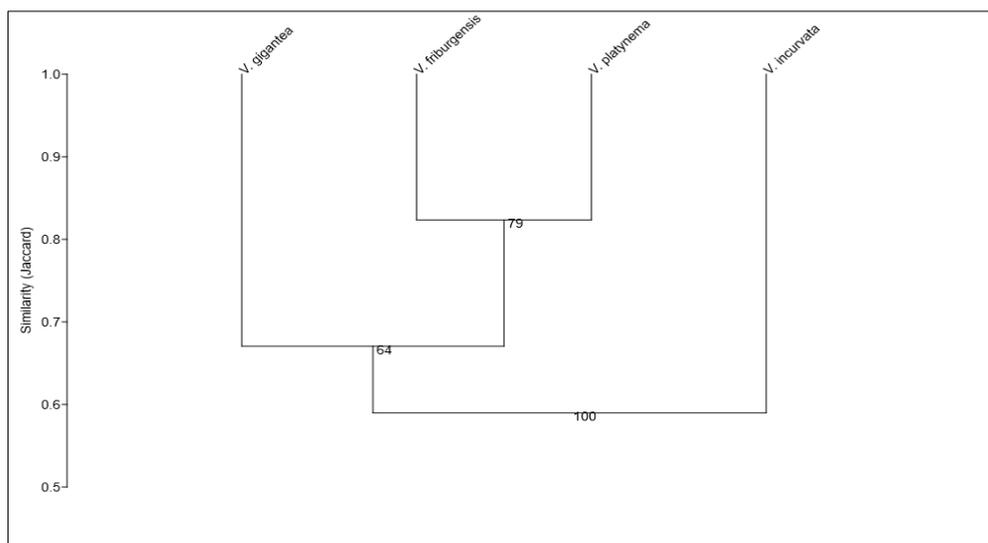


Figure 5. Jaccard similarity index cladogram with the similarities between the different *Vriesea* spp. Based on data set collected from Sept. 2017 to Oct. 2018, in a mountain range from Serra Geral, southern Brasil.

The results showed a strong similarity in the phytotelmata community composition between the two bromeliad species collected in Pró-Mata (0.79). *V. gigantea* was also more similar to the species collected at high altitude than to *V. incurvata*, collected at middle altitude. The cladograma data set encompasses the occurrence of morphospecies shared with each bromeliad species, and also exclusive occurrences of morphospecies in one bromeliad species.

#### *Aechmea gamosepala* phytotelm community

The eukaryotic assemblage that inhabits the bromeliad species *Aechmea gamosepala* in Pró-Mata and Garapia River was very similar to the one found in different species of *Vriesea*. This assemblage was basically constituted by 30 morphospecies, distributed among: Ciliophora (16), Arthropoda (9), Rotifera (2), Annelida (1), Nematoda (1), and Plathelmyntes (1). All morphospecies found in *A. gamosepala* at each altitude can be seen in Table 3.

Table 2. Eukaryotic community assemblage found in the phytotelmata of *Aechmea gamosepala* distributed among a mountain range in Serra Geral, Rio Grande do Sul, Brazil.

Morphospecies	<i>A. gamosepala</i> (915m)	<i>A. gamosepala</i> (400m)
<b>Rotifera</b>		
Philodinidae I	*	*
Philodinidae II	-	*
<b>Ciliophora</b>		
<i>Lambornella trichoglossa</i>	*	*
<i>Paramecium caudatum</i>	*	*
<i>Glaucoma</i> sp.	*	*
<i>Colpoda</i> sp.	*	*
<i>Tetrahymena</i> sp.	*	*
Unidentified ciliate (Tetrahymenidae)	*	-
<i>Halteria</i> sp.	*	*
<i>Rabdostyla</i> sp.	*	*
<i>Euplotes</i> sp.	*	*
<i>Loxodes</i> sp.	*	*
<i>Discomorphella</i> sp.	*	*
<i>Spirostomum</i> sp.	*	-
Hipotrichia	*	*
Not identified I	*	-
Not identified II	*	-
<i>Vorticella</i> sp.	-	*
<b>Arthropoda</b>		
<i>Atheyella fuhrmani</i> (Copepode)	*	*
Culicidae larvae I (Diptera)	*	*
Culicidae larvae II (Diptera)	*	*
Scirtidae larvae (Coleoptera)	*	*
Chironomidae larvae I (Diptera)	*	*

Chironomidae larvae II (Diptera)	*	*
<i>Elpidium bromeliarum</i> (Ostracode)	*	*
Elpidium sp. II (Ostracode)	*	*
Acari (Chelicerata)	*	*
<b>Annelida</b>		
<i>Dero</i> sp.	*	*
<b>Nematoda</b>		
Nematode	*	-
<b>Platyhelminthes</b>		
Flatworm I	*	-

Author, 2019.

Species richness of the phytotelmata community of *A. gamosepala* for the two sampled altitudes are shown in Figure 6. The bromeliads that occur in Pró-Mata presented more morphospecies present in their phytotelms in comparison with individuals collected in Garapiá River. A total of 28 species were present in *A. gamosepala* from high altitudes, while 24 occurred in the middle altitude.

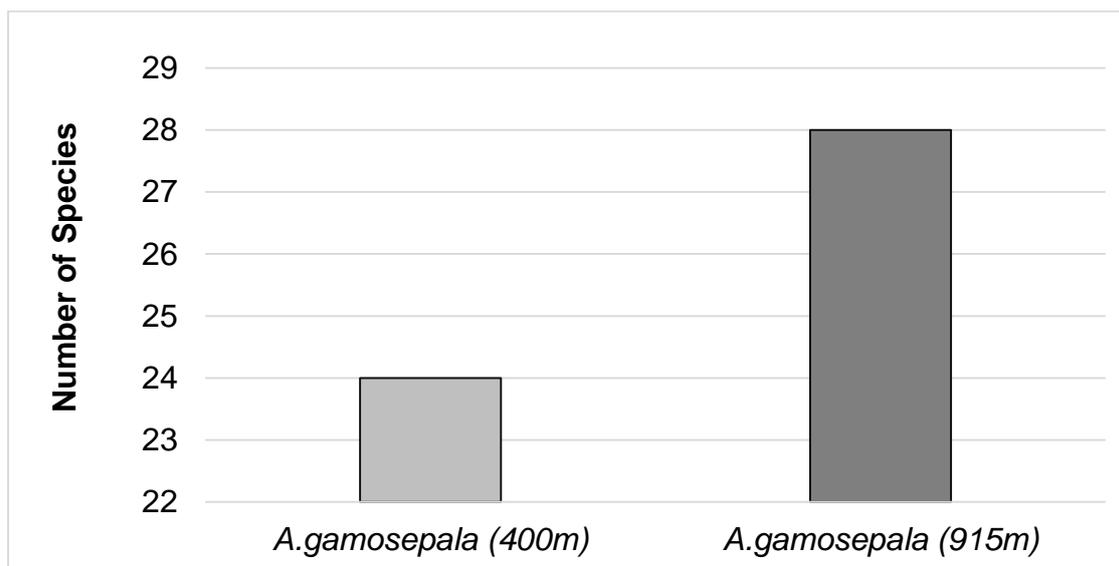


Figure 6. Phytotelm community species richness for *Aechmea gamosepala* Wittm.. distributed along a mountain range in Serra Geral, Rio Grande do Sul (BR) based on data collected during the study period (Oct./2017-Sept./2018).

The richness variation of the community and the most representative groups in the phytotelmata of each altitude sampled are shown in Figure 7. *A. gamosepala* at middle altitude showed an average of 8.17 morphospecies, while the high altitude bromeliads presented 8.63 morphospecies their phytotelmata.

ANOVA analyses, as in *Vriesea* phytotelmata community, did not show statistically significant difference on specific richness of the most representative groups at different altitudes.

The richness variation of the ciliate assemblage showed an increasing peak at high altitude, compared with the community collected in middle altitude. An average of 4.83 morphospecies were present in bromeliads collected in Pró-Mata, while 3.88 morphospecies were present in individuals from Garapiá Stream. For the arthropod community, the middle altitude presented the highest number of species (3.29 morphospecies), while individuals at high altitude had an average of 2.46 morphospecies. The rotifer community for both altitudes were very similar, with an average of 0.71 and 0.83 morphospecies in the middle and high altitudes, respectively.

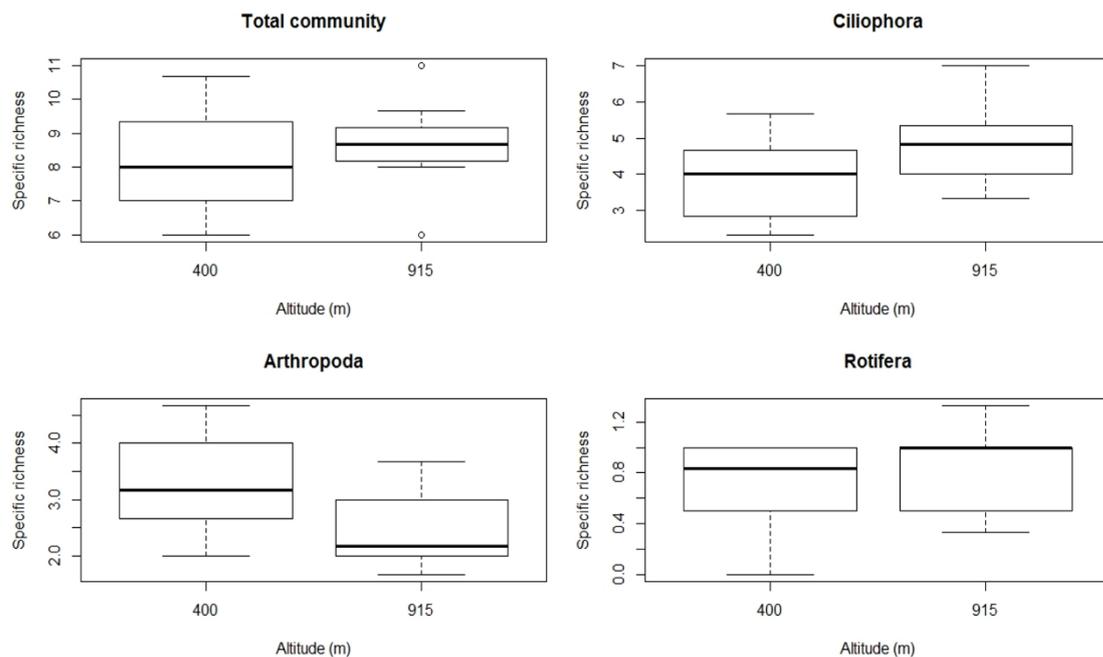


Figure 7. Richness average of the phytotelmata community among individuals of *Aechmea gamosepala* distributed at two different altitudes (Garapiá River – 400m; Pró-Mata – 915m).

#### *Seasonal variation of Aechmea gamosepala phytotelmata community*

The occurrence and abundance of each morphospecies present in *Aechmea gamosepala* and their seasonal variance were estimated by the average of their presence in each bromeliad individual. Like in *Vriesea* community, we considered a maximum value for nematode abundance (30) due to their high presence in the samples. In this way, the histogram graphics and the occurrence of rare organisms are clear to understand. The figure 8 shows a comparison between the communities and their frequency in *A. gamosepala* from middle and high altitude.

At both altitudes, there was a high frequency of Nematoda, as observed for *Vriesea* species. The rotifer community, composed by two morphospecies, had only one species occurring at high altitude (Philodinidae I), with a peak of 8.50 ind./ml during the autumn. In Garapiá River, individuals of *A. gamosepala* harbored another morphospecies (Philodinidae II), that occurred only in the

winter with an average of 0.33 ind./ml. Philodinidae I also occurred in the middle altitude with a peak of 10.67 ind./ml during the spring.

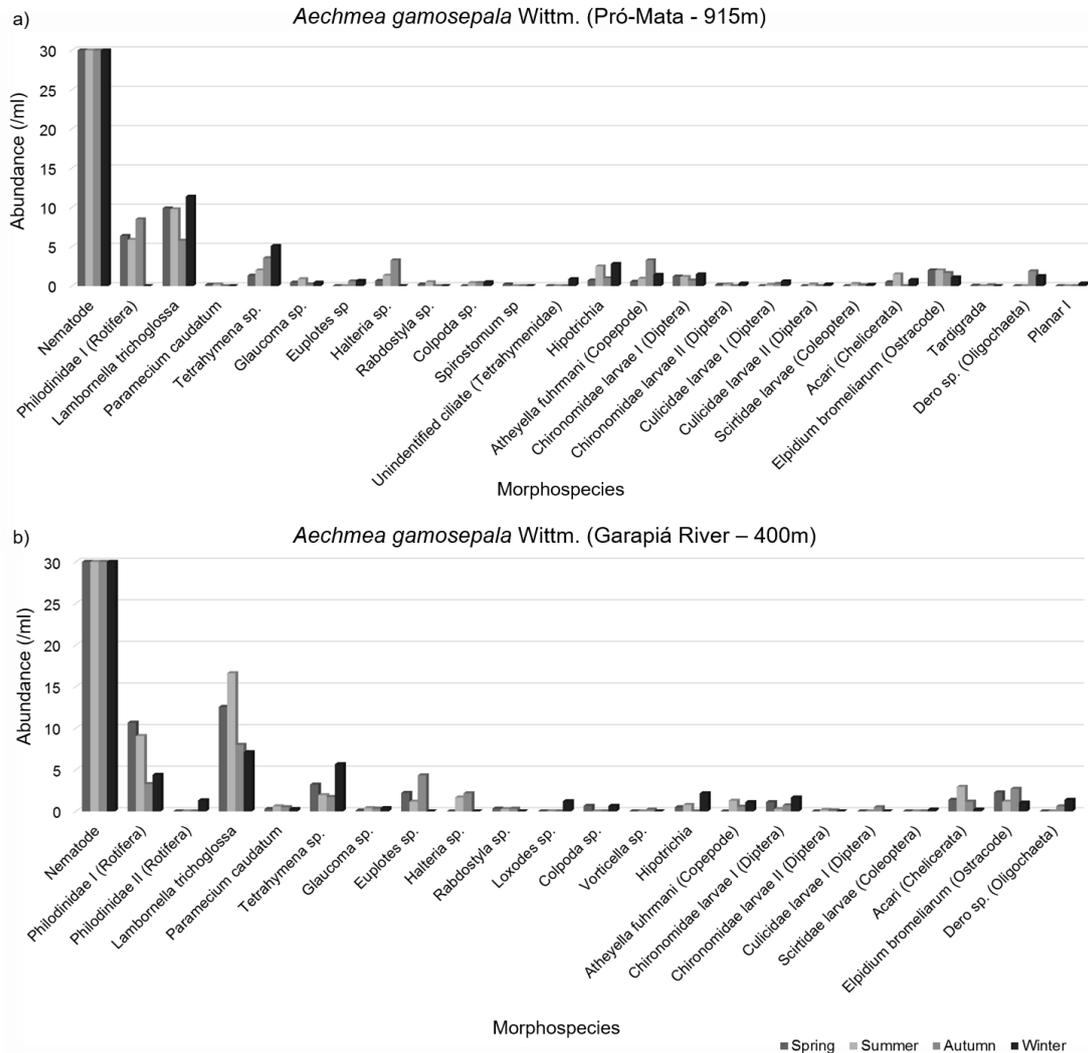


Figure 8. Seasonal variation of *Aechmea gamosepala* phytotelmata community. The ciliate assemblage are expressed mostly at genus level, while the other groups are specified inside the parenthesis. a) Pró-Mata (915 m); b) Garapiá River (400m).

The ciliate assemblage at both altitudes were very similar, except *Loxodes* sp. that appeared only in the winter (1.22 ind./ml) and *Vorticella* sp. during autumn (0.22 ind./ml) exclusively in Garapiá River. Another two morphospecies, *Spirostomum* sp. and the unidentified tetrahymenidae ciliate (also observed in *Vriesea*) were found only in Pró-Mata. *Spirostomum* sp. was recorded only in the spring (0.22 ind./ml) while the tetrahymenid ciliate occurred in the winter (0.89 ind./ml).

*Lambornella trichoglossa*, as observed for *Vriesea* phytotelmata communities, was the most representative ciliate in individuals of *Aechmea gamosepala*. A total average of 11.07 ind./ml was estimated in the middle altitude, with a peak of occurrence in the summer (16.61 ind./ml). In the higher altitude, it was observed a peak of 11.39 ind./ml during the winter. *Tetrahymena* sp. was also a

common ciliate morphospecies for both altitudes, as well as *Glaucoma* sp., *Loxodes* sp., *Rabdostyla* sp., *Colpoda* sp., *Halteria* sp., *Euplotes* sp., *Paramecium caudatum* and hypotrich. ciliates, as observed for species of *Vriesea*. The mean number of individuals of each morphospecies found in *A. gamosepala* phytotelmata are found in Appendix V and VI.

The arthropod community found in individuals of *A. gamosepala* was very similar at both altitudes, with some exclusive occurrences. For example, *Atheyella fuhrmani*, showed its highest abundance in Pró-Mata during the autumn (3.28 ind./ml), while in Garapiá River it peaked in summer (1.28 ind./ml).

Two morphospecies of Chironomidae larvae occurred at both altitudes, as they are top predators in the phytotelmata environment. Chironomidae larvae I occurred in high densities in Pró-Mata, with a total average of 1.15 ind./ml, while Chironomidae larvae II presented an abundance of 0.18 ind./ml. In the middle altitude, both morphospecies occurred, with highest density of Chironomidae larvae I (0.95 ind./ml) in comparison with Chironomidae larvae II (0.07 ind./ml).

Morphospecies of Culicidae larvae were also found in individuals of *A. gamosepala*. In Pró-Mata, two morphospecies occurred with a total abundance of 0.27 ind./ml and 0.11 ind./ml for Culicidae larvae I and II, respectively. In Garapiá River, only Culicidae larvae I appeared in the autumn with an abundance of 0.50 ind./ml. Coleopteran larvae from the family Scirtidae had a highest density and occurrence in the bromeliads from high altitude. They were present in all seasons (except during spring), with a total average of 0.14 ind./ml. In the middle altitude they were recorded only in the winter (0.22 ind./ml).

*Elpidium bromeliarum* (Ostracoda) and one morphospecies of a mite were also found in individuals of *A. gamosepala*. High density of both organisms were observed in Garapiá river with a total average of 1.43 ind/ml of *E. bromeliarum* and 1.81 ind./ml of the mite morphospecies. The mite morphospecies presented its highest peak in the summer, while *E. bromeliarum* showed high occurrence in the autumn. In Pró-Mata, they also occurred in representative populations, with 0.70 and 1.70 ind./ml for each morphospecies, respectively.

*Dero* sp. and Flatworm I were also present in phytotelmata of *A. gamosepala*. While *Dero* sp. appears in both altitudes with an abundance of 0.79 ind./ml in Pró-Mata and 0.50 ind./ml in Garapiá river, Flatworm I appears only at the high altitude in the winter (0.08 ind./ml). A species of tardigrade was observed in bromeliad individuals collected in Pró-Mata. This species was recorded in spring with an abundance of 0.06 ind./ml, and in autumn reaching 0.11 ind./ml.

## DISCUSSION

Rahbek (1995, 1997) reviewed data sets from tropical and non-tropical areas with an elevational range from below 500 m to above 1500 m. He found three patterns of species distribution: the 'typical' monotonic decline, a unimodal pattern, and a third pattern characterized by a species richness curve that was almost horizontal up to a certain elevation before declining rapidly at high elevation. Richardson (1999) used the bromeliad phytotelm ecosystem to compare diversity at different altitudes in the Luquillo Experimental Forest, Puerto Rico. Three altitude levels were sampled, and the peak of species richness was observed at intermediate altitude. Abundance data, on the other hand, revealed that diversity decreased as elevation increased. According to Körner (2007) there are four main abiotic factors that change with increasing altitude: decline of land area; decrease in total atmospheric pressure and partial pressure of O<sub>2</sub> and CO<sub>2</sub>; reduction of air temperature; and increase in solar radiation. In the present study, although there was no statistically significant difference, a tendency of high specific richness was found in *V. incurvata* which occurs at middle altitude. In addition, qualitative samples demonstrated a very diverse eukaryotic community present in the tanks of *V. incurvata*. Boxplots (Figure 3) show that considering all the community and the most representative groups, highest abundances are found in the tanks of bromeliads collected at middle altitudes. Qualitative analyses have also demonstrated exclusive occurrences of species in the phytotelmata of *V. incurvata*. One example is the occurrence of the ciliate *Lagernophrys* sp. as an epibiont on ostracods, as well as *Rabdostyla* sp. attached to mites.

A key factor for success in phytotelmata communities is the mode and rate of dispersal of their inhabitants. Becker and Camargo (1999) have suggested that species of amphibians are potential dispersers of *Elpidium* sp. (Ostracode) and *Dero* sp. (Naididae/Oligochaeta). In an experimental study, these authors found individuals of *Elpidium* and *Dero* attached to the skin of *Xenohyla truncata* (Hylidae/Anura), and suggested that the invertebrates may use their host as a disperser agent. Moreover, the same genus of ostracod was observed attached to the skin of *Leptodeira* sp., a snake collected from the tanks of *Aechmea nudicaulis* in Barra de Maricá, which may also act in the dispersion of these crustaceans (Becker and Camargo, 1999). *Dero* and *Elpidium* were present in all bromeliad individuals sampled in the present study, which could suggest that dispersal events may be occurring, since the bromeliads sampled were located in forest areas, that harbor frogs and snakes, which could act as phoretic agents of dispersion. The epibiotic relationship observed aquatic invertebrates and peritrichs in the present study is also a dispersion mode for the epibiont since it could be transported throughout the cisterns by its host (Cabral *et al.*, 2010)

Organisms that live in bromeliad water need to cope with abundance and shortage of water as well as abundance and scarcity of food. Several organisms are capable of dispersion when the conditions are deteriorating, but those that cannot disperse easily generally are able to make cysts or enter dormant stages until the environmental conditions are restored. When the food is scarce, many species of ciliates can change the body size to be able to graze on a different prey size (Clegg, 2001). For example, Foissner *et al.* (2003) found

that several species of ciliates from tank bromeliads could switch from a small, bacteriophagous, microstome morphotype to a large, predatory, macrostome lifestyle. This switch is probably due to the strong competition that these communities undergo at certain times. In this study, the unidentified tetrahymenid ciliate was observed in a macrostome stage that fed on *Paramecium caudatum* and microstomes that were mainly bacterivores. The presence of these different morphotypes suggest that the sampled bromeliads present fluctuations in food availability which could be due competition among species present in the phytotelmata. The ciliate assemblage found in the sampled bromeliads included genera reported from soil samples (e.g. *Colpoda*) as well as limnetic ciliates that are very common in freshwater environments (e.g. *Tetrahymena*, *Halteria*, *Pleuronema*, *Vorticella*) demonstrating that phytotelmata are composed by a mixture assemblage of soil and freshwater as suggested by (Foissner, 2003).

In addition to morphological analyses of the ciliate assemblage present in bromeliad water (Foissner, 2003), molecular analyses have also been performed to assess the diversity of these organisms in phytotelmata. For example, Dunthorn *et al.* (2012) using molecular analyses found representatives of almost all ciliate classes in bromeliads collected in Brazil, Costa Rica, Dominican Republic, Jamaica and. Simão *et al.* (2017) performed metabarcoding analyses of tank water of individuals of *V. platymena*, *V. friburgensis* and *A. gamosepala* from Pró-Mata and found that the dominant genus of ciliate was *Tetrahymena*. In the present study, also the genus *Tetrahymena* was present in high abundance in all collected individuals of bromeliads at all altitudes confirming that this ciliate is a common inhabitant of bromeliad waters. In terms of abundance, *Lambornella trichoglossa* was the ciliate species that dominated in all bromeliad individuals sampled at all altitudes. This hymenostome ciliate was first described by Foissner (2003) from bromeliads from northeast Brazil, and have been regularly reported by other studies (e.g. Buosi *et al.*, 2015).

Tank bromeliads promote a trophic web diversity in Neotropical forests amplifying the diversity of dynamics in this phytogeographical region (Brouard *et al.* 2012). Carrias *et al.* (2001) investigated the importance of the protozoans in this microenvironment and concluded that they are key agentes in these systems, stimulating the degradation of accumulated organic matter. They also found a positive correlation between protozoan abundance and the presence of microinvertebrates, such as rotifers, copepods and mosquito larvae. In this study, the co-occurrence of a rich ciliate assemblage, different arthropod morphospecies, and rotifer community in the sampled bromeliads, demonstrate a complete trophic web present in the phytotelmata, with representative species occurring in all seasons and altitudes sampled.

The study area comprises a mountain range in Southern areas of Serra Geral in Rio Grande do Sul, where the lower areas were situated next to Maquiné city. The urban influence on the diversity of phytotelmata of lower altitude can be noticed by the presence of Psychodidae larvae in *V. gigantea* phytotelmata community. This mosquito family is well adapted to environments with antropic intervention (Ximenes *et al.* 2007) and are known as bathroom mosquitoes. The places where the bromeliads were sampled is under high antropic intervention.

Other diverse mosquitoes families (Chorinomidae, Culicidae, Certapogonidae and Thaumalidae) also occurred in the studied bromeliads. Immature forms of 214 species of culicids have been found in bromeliad waters (Frank and Curtis, 1981). A study conducted by Muller and Marcondes (2006) about the bromeliad associated mosquitoes from Atlantic forest in Santa Catarina (southern Brazil), found high abundance of eight *Culex* sp. larvae in *V. friburgensis*. In our study, *V. friburgensis* from Pró-Mata not only presented two Culicidae larvae morphospecies, but also had a high abundance compared to the other bromeliads sampled. The high abundance of mosquitoes larvae may be due to the imbricate arrangement of the leaves, forming small cavities (Muller and Macondes, 2016)

The high degree of preservation in the Garapiá trails may be related to the high occurrence of diptera larvae in *V. incurvata* phytotelmata. In this area, a high population density of this bromeliad species was found on canopies, which can help to explain the high phytotelmata community diversity tendency observed in the present study. This diversity may be due to many possibilities of intersharing of dispersed individuals. According to O'mera *et al.* (2003), the native bromeliads tend to hold a higher diversity of mosquito larvae compared with introduced bromeliads, which could lead a problem of public health, once several mosquito species are diseases transmitters.

In Simão *et al.* (2017), the ciliate assemblage was the second most representative group, with also predominance of mosquito larvae and annelids. Goffredi *et al.* (2015) had found a similar result for bromeliads from Costa Rica. In their study, metatranscriptome analyses revealed great abundance of annelids and insect larvae. Studies focusing on the invertebrate community present in bromeliad waters had also pointed out the dominance of arthropods and annelids (Picado, 1913; Richardson, 1999; Zotz and Traunspurger, 2016). The high frequency of annelids and arthropods reported in bromeliad tank waters could explain the high abundance of apicomplexans gregarines found in molecular analysis of Pró-Mata bromeliads analyzed by Simão *et al.* (2017), once apicomplexans are unicellular endosymbionts and are generally found in association with aquatic oligochaetes and arthropods (Hausmann *et al.*, 2003).

The seasonal variance between the communities of different bromeliads shown interesting patterns of peak of frequency of organisms. This fluctuation in population density of different organisms led to the pattern observed in the present study. For example, *V. platynema*, *V. friburgensis*, and *A. gamosepala* (Pró-Mata bromeliads) had a density peak of organisms during summer, while for *V. incurvata* and *V. gigantea*, it peaks during the autumn and winter, respectively. The increasing number of studies focusing on seasonal variances in bromeliad communities could help to better explain different patterns of the phytotelm community.

An interesting data found in the quantitative analyses is the tardigrad morphospecies occurring in *A. gamosepala* individuals of higher altitude. The tardigrades were only found in Pró-Mata, suggesting that there is a population distributed in these bromeliads, and they are adapted to the limits of increasing altitude. Some responses to environmental fluctuations of these environments are

cryptobiosis and anhydrobiosis in tardigrada (Halberg et al., 2013), rotifers (Marotta *et al.*, 2010) and nematodes (Banton and Tunnacliffe, 2012). These processes consist of molecular and morphophysiological adaptations resulting in total reduction of metabolism during periods of drought, with return of activity after hydration (Clegg, 2001). The leaves of *A. gamosepala* appear to be thinner than *Vriesea* species, which concentrates a lot of organic matter and acidifies the aquatic environment, and may be limiting organisms' occurrence in this bromeliad species.

In conclusion, phytotelmata communities of *Vriesea* species and *Aechmea gamosepala* bromeliads distributed at different altitudes showed interesting patterns of composition and species occurrence. *Vriesea* and *Aechmea* are the genera with the highest species richness in the bromeliad family. Sampling of different phytotelmata bromeliad species in a mountain range not only can reveal a hidden biodiversity inside the group, but also how ecological patterns and dynamics can be applied to the community of these environments. The appearance of different ciliate species at different altitudes, as well as other eukaryotic organisms, showed some tendencies of altitudinal patterns of distribution, although more studies are needed to confirm this tendency. Also, from this study, it can be concluded that these cisterns harbor a great diversity of organisms, where many of them spend their entire life cycle, while others use them only at certain life stages, stressing the importance of these environments as amplifiers of biodiversity, and their potential use in plans for conservation of the Atlantic Forest biodiversity.

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## Appendix I

Table 3. *Vriesea platynema* Gaudich. phytotelm community and their seasonal variance.

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30,00	30,00	30,00	30,00	30,00
Philodinidae I (Rotifera)	3,83	4,56	6,28	9,83	6,13
Philodinidae II (Rotifera)	0,17	0,11	1,50	0,67	0,61
<i>Lambornella trichoglossa</i>	3,06	8,67	7,56	6,45	6,43
<i>Paramecium caudatum</i>	0,33	0,22	0,61	0,28	0,36
<i>Tetrahymena</i> sp.	3,67	6,00	5,94	1,28	4,22
<i>Glaucoma</i> sp.	0,11	0,00	0,00	0,50	0,15
<i>Euplotes</i> sp.	3,33	4,11	2,06	1,50	2,75
<i>Halteria</i> sp.	1,22	1,78	0,22	0,56	0,94
<i>Rabdostyla</i> sp.	0,67	0,33	0,28	0,00	0,32
<i>Loxodes</i> sp.	0,44	0,17	0,00	0,00	0,15
<i>Colpoda</i> sp.	0,11	0,00	0,00	0,50	0,15
<i>Vorticella</i> sp.	0,22	0,00	0,00	0,00	0,06
<i>Discomorphella</i> sp.	0,00	0,06	0,00	0,06	0,03
<i>Stentor</i> sp.	0,11	0,00	0,00	0,00	0,03
Unidentified ciliate (Tetrahymenidae)	0,67	0,28	0,67	0,00	0,41
Hipotrichia	0,06	0,94	1,33	0,11	0,61
<i>Atheyella fuhrmani</i> (Copepode)	0,78	6,00	0	0	1,70
Chironomidae larvae I (Diptera)	0,89	0,28	1,44	0,33	0,74
Chironomidae larvae II (Diptera)	0,11	1,44	0,11	0,00	0,42
Culicidae larvae I (Diptera)	0,11	0,06	0,89	0,56	0,40
Scirtidae larvae (Coleoptera)	0,11	0,06	0,50	0,72	0,35
Acari (Chelicerata)	0,00	0,39	0,33	0,56	0,32
<i>Elpidium bromeliarum</i> (Ostracode)	2,73	0,72	4,50	2,72	2,67
<i>Dero</i> sp. (Oligochaeta)	0,67	0,11	1,78	1,56	1,03

Author, 2019.

## Appendix II

Table 4. *Vriesea friburgensis* Gaudich. phytotelm community and their seasonal variance.

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30,00	30,00	30,00	30,00	30,00
Philodinidae I (Rotifera)	2,28	15,17	10,17	10,61	9,56
Philodinidae II (Rotifera)	0,06	0,33	2,11	1,56	1,02
<i>Lambornella trichoglossa</i>	3,22	22,00	10,78	7,22	10,81
<i>Paramecium caudatum</i>	0,28	0,17	0,11	0,00	0,14
<i>Tetrahymena</i> sp.	1,89	6,05	5,22	5,89	4,76
<i>Glaucoma</i> sp.	0,00	3,00	2,50	0,00	1,38
<i>Euplotes</i> sp.	1,00	2,11	1,83	0,00	1,24
<i>Halteria</i> sp.	0,72	0,39	0,56	0,00	0,42
<i>Rabdostyla</i> sp.	0,78	0,06	0,00	0,33	0,29
<i>Loxodes</i> sp.	0,00	2,17	0,83	0,39	0,85
<i>Colpoda</i> sp.	0,00	0,17	0,00	0,44	0,15
<i>Spirostomum</i> sp.	0,06	0,00	0,00	0,00	0,02
Unidentified ciliate (Tetrahymenidae)	0,17	1,22	2,33	3,67	1,85
Hipotrichia	0,00	1,17	0,72	2,17	1,02
<i>Atheyella fuhrmani</i> (Copepode)	0,11	0,22	0,00	0,00	0,08
Chironomidae larvae I (Diptera)	0,50	0,94	1,45	0,95	0,96
Chironomidae larvae II (Diptera)	0,00	0,39	0,00	0,00	0,10
Culicidae larvae I (Diptera)	0,06	0,00	0,89	1,06	0,50
Culicidae larvae II (Diptera)	0,00	0,00	0,50	0,00	0,13
Scirtidae larvae (Coleoptera)	0,00	0,39	0,28	0,22	0,22
Acari (Chelicerata)	0,06	0,50	0,11	0,89	0,39
<i>Elpidium bromeliarum</i> (Ostracode)	1,33	3,67	1,00	0,94	1,74
<i>Dero</i> sp. (Oligochaeta)	0,06	0,00	0,00	0,39	0,11
Planar II (Plathyhelmynthe)	0,00	0,00	0,17	0,00	0,04

Author, 2019.

### Appendix III

Table 5. *Vriesea incurvata* Gaudich. phytotelm community and their seasonal variance.

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30	30	30	30	30
Philodinidae I (Rotifera)	1,39	4,72	7,56	5,67	4,84
Philodinidae II (Rotifera)	0,00	0,39	0,28	2,06	0,68
<i>Lambornella trichoglossa</i>	3,39	5,28	10,00	15,11	8,45
<i>Paramecium caudatum</i>	0,17	0,72	0,11	0,39	0,35
<i>Tetrahymena</i> sp.	0,67	7,22	7,28	4,72	4,97
<i>Glaucoma</i> sp.	0,56	1,67	0,56	0,45	0,81
<i>Euplotes</i> sp.	1,50	0,89	3,06	2,11	1,89
<i>Halteria</i> sp.	1,28	1,11	0,61	4,17	1,79
<i>Rabdostyla</i> sp.	0,67	0,06	0,17	0,00	0,23
<i>Loxodes</i> sp.	1,78	0,00	2,33	0,00	1,03
<i>Colpoda</i> sp.	0,06	0,00	0,00	0,11	0,04
<i>Lagernophrys</i> sp.	6,61	17,83	12,06	3,78	10,07
<i>Vorticella</i> sp.	0,06	0,00	0,00	0,00	0,02
<i>Trochilia</i> sp.	0,00	0,06	0,06	0,00	0,03
Hipotrichia	0,22	1,45	0,22	0,78	0,67
<i>Atheyella fuhrmani</i> (Copepode)	4,22	9,50	7,11	7,39	7,06
Chironomidae larvae I (Diptera)	0,72	0,50	1,89	0,95	1,02
Chironomidae larvae II (Diptera)	0,11	0,17	0,28	0,00	0,14
Culicidae larvae I (Diptera)	0,00	0,45	0,45	0,00	0,23
Culicidae larvae II (Diptera)	0,00	0,00	0,17	0,06	0,06
Ceratopogonidae larvae I (Diptera)	0,00	0,00	0,00	0,17	0,04
Scirtidae larvae (Coleoptera)	0,00	0,00	0,22	0,39	0,15
Acari (Chelicerata)	0,44	0,67	0,00	0,45	0,39
<i>Elpidium bromeliarum</i> (Ostracode)	1,78	2,61	2,14	1,33	1,97
<i>Dero</i> sp. (Oligochaeta)	0,00	0,06	1,78	1,17	0,75
Oligochaeta II	0,00	0,00	0,11	0,00	0,03
Planar II (Plathyelmynthe)	0,00	0,00	0,00	0,11	0,03

Author, 2019.

## Appendix IV

Table 6. *Vriesea gigantea* Gaudich. phytotelm community and their seasonal variance

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30,00	30,00	30,00	30,00	30,00
Philodinidae I (Rotifera)	8,22	3,17	5,89	4,28	5,39
Philodinidae II (Rotifera)	0,00	0,00	0,72	0,39	0,28
<i>Lambornella trichoglossa</i>	10,17	5,33	9,72	10,44	8,91
<i>Paramecium caudatum</i>	0,50	0,00	0,00	0,00	0,13
<i>Tetrahymena</i> sp.	1,11	3,89	1,78	3,78	2,64
Glaucoma sp.	1,11	0,94	0,28	0,22	0,64
<i>Euplotes</i> sp.	0,00	0,83	0,00	2,17	0,75
<i>Halteria</i> sp.	0,00	0,67	1,28	1,50	0,86
<i>Rabdostyla</i> sp.	0,78	0,00	0,39	0,00	0,29
<i>Loxodes</i> sp.	0,00	0,00	1,50	0,00	0,38
<i>Colpoda</i> sp.	1,34	0,28	0,00	0,22	0,46
<i>Spirostomum</i> sp.	0,22	0,06	0,00	0,00	0,07
<i>Metopus</i> sp.	0,00	0,00	0,00	3,28	0,82
Hipotrichia	0,00	0,56	1,33	0,78	0,67
Unidentified ciliate (Tetrahymenidae)	0,22	0,00	0,00	0,00	0,06
<i>Atheyella fuhrmani</i> (Copepode)	0,00	2,11	0,00	0,00	0,53
Chironomidae larvae I (Diptera)	0,00	0,00	0,11	0,11	0,06
Chironomidae larvae II (Diptera)	0,00	0,28	0,00	0,00	0,07
Culicidae larvae II (Diptera)	0,00	0,00	0,72	0,11	0,21
Ceratopogonidae larvae I (Diptera)	0,00	0,00	0,11	0,11	0,06
Ceratopogonidae larvae II (Diptera)	0,00	0,00	0,00	0,17	0,04
Psychodidae larvae (Diptera)	0,00	0,00	0,00	0,06	0,02
Scirtidae larvae (Coleoptera)	0,00	0,00	0,00	0,28	0,07
Acari (Chelicerata)	0,50	1,78	0,78	0,00	0,77
<i>Elpidium bromeliarum</i> (Ostracode)	1,28	3,33	2,44	2,17	2,30
<i>Dero</i> sp. (Oligochaeta)	0,83	0,56	1,56	0,61	0,89
Planar I (Plathyelmynthe)	0,11	0,00	0,00	0,00	0,03
Planar II (Plathyelmynthe)	0,17	0,00	0,00	0,00	0,04

Author, 2019.

## Appendix V

Table 7. *Aechmea gamosepala* Wittm. (Pró-Mata – 900m) phytotelm community and their seasonal variance.

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30,00	30,00	30,00	30,00	30,00
Philodinidae I (Rotifera)	6,39	5,89	8,50	0,00	5,20
<i>Lambornella trichoglossa</i>	9,89	9,78	5,78	11,39	9,21
<i>Paramecium caudatum</i>	0,17	0,22	0,00	0,00	0,10
<i>Tetrahymena</i> sp.	1,33	2,00	3,56	5,11	3,00
<i>Glaucoma</i> sp.	0,45	0,89	0,22	0,45	0,50
<i>Euplotes</i> sp.	0,00	0,00	0,61	0,67	0,32
<i>Halteria</i> sp.	0,67	1,33	3,28	0,00	1,32
<i>Rabdostyla</i> sp.	0,22	0,50	0,00	0,00	0,18
<i>Colpoda</i> sp.	0,00	0,39	0,39	0,50	0,32
<i>Spirostomum</i> sp.	0,22	0,00	0,00	0,00	0,06
<i>Unidentified ciliate (Tetrahymenidae)</i>	0,00	0,00	0,00	0,89	0,22
Hipotrichia	0,72	2,50	1,00	2,83	1,76
<i>Atheyella fuhrmani</i> (Copepode)	0,56	0,94	3,28	1,44	1,56
Chironomidae larvae I (Diptera)	1,22	1,17	0,72	1,50	1,15
Chironomidae larvae II (Diptera)	0,17	0,22	0,00	0,33	0,18
Culicidae larvae I (Diptera)	0,00	0,17	0,28	0,61	0,27
Culicidae larvae II (Diptera)	0,00	0,22	0,00	0,22	0,11
Scirtidae larvae (Coleoptera)	0,00	0,28	0,11	0,17	0,14
Acari (Chelicerata)	0,50	1,50	0,00	0,78	0,70
<i>Elpidium bromeliarum</i> (Ostracode)	2,00	2,00	1,67	1,11	1,70
Tardigrada	0,06	0,00	0,11	0,00	0,04
<i>Dero</i> sp. (Oligochaeta)	0,00	0,00	1,89	1,28	0,79
Planar I	0,00	0,00	0,00	0,33	0,08

Author, 2019.

## Appendix VI

Table 8. *Aechmea gamosepala* Wittm. (Garapiá River – 400m) phytotelm community and their seasonal variance.

Morphspecies	Spring (n° ind/ml)	Summer (n° ind/ml)	Autumn (n° ind/ml)	Winter (n° ind/ml)	Total (n° ind/ml)
Nematode	30,00	30,00	30,00	30,00	30,00
Philodinidae I (Rotifera)	10,67	9,06	3,28	4,39	6,85
Philodinidae II (Rotifera)	0,00	0,00	0,00	1,33	0,33
<i>Lambornella trichoglossa</i>	12,56	16,61	8,00	7,11	11,07
<i>Paramecium caudatum</i>	0,28	0,61	0,50	0,28	0,42
<i>Tetrahymena</i> sp.	3,22	1,95	1,72	5,67	3,14
<i>Glaucoma</i> sp.	0,11	0,39	0,33	0,39	0,31
<i>Euplotes</i> sp.	2,22	1,17	4,33	0,00	1,93
<i>Halteria</i> sp.	0,00	1,67	2,17	0,00	0,96
<i>Rabdostyla</i> sp.	0,33	0,28	0,33	0,00	0,24
<i>Loxodes</i> sp.	0,00	0,00	0,00	1,22	0,31
<i>Colpoda</i> sp.	0,67	0,00	0,00	0,67	0,34
<i>Vorticella</i> sp.	0,00	0,00	0,22	0,00	0,06
Hipotrichia	0,50	0,78	0,00	2,17	0,86
<i>Atheyella fuhrmani</i> (Copepode)	0,00	1,28	0,56	1,11	0,74
Chironomidae larvae I (Diptera)	1,11	0,28	0,72	1,67	0,95
Chironomidae larvae II (Diptera)	0,00	0,17	0,11	0,00	0,07
Culicidae larvae I (Diptera)	0,00	0,00	0,50	0,00	0,13
Scirtidae larvae (Coleoptera)	0,00	0,00	0,00	0,22	0,06
Acari (Chelicerata)	1,39	2,95	1,17	0,22	1,43
<i>Elpidium bromeliarum</i> (Ostracode)	2,28	1,17	2,72	1,06	1,81
<i>Dero</i> sp. (Oligochaeta)	0,00	0,00	0,61	1,39	0,50

Author, 2019.

## CAPÍTULO III

### **Considerações finais**

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## CONSIDERAÇÕES FINAIS

O fitotelmo das bromélias, por muitos autores, pode carregar diversas perspectivas quanto ao seu papel na natureza. Além de um organismo vegetal, com sua biologia específica, estas plantas podem ser consideradas lagos suspensos, abrigando uma comunidade altamente diversificada e adaptada às limitações deste ambiente. Entender os processos ecológicos que acabam atuando sobre a comunidade fitotelmática pode, muitas vezes, ser difícil de mensurar. À medida que o conhecimento taxonômico sobre a composição faunística deste ambiente aumenta, torna-se mais fácil entender as dinâmicas e forças que moldam as comunidades.

Os dados provenientes deste estudo mostram um rico microcosmo composto por diversos filos de invertebrados aquáticos, desde pequenos ciliados filtradores até larvas de mosquitos predadoras de topo, além de outros animais suspensívoros e comedores de depósito. Os resultados deste estudo permitiram não só avaliar a composição da comunidade fitotelmática, mas seu nível de similaridade quando comparada com a fauna de outras bromélias do mesmo gênero. Foi possível observar grande parte da diversidade fitotelmática sendo compartilhada entre as bromélias de diferentes espécies, em diferentes altitudes, bem como a ocorrência de morfoespécies exclusivas entre elas. A similaridade da composição da comunidade entre as bromélias do Pró-Mata, corroboradas pelo índice de Jaccard, evidenciam uma série de eventos de dispersão dos microrganismos que podem estar envolvido nas semelhanças encontradas. Além disso, a partir dos dados levantados, pode-se perceber que assim como ocorre em outras comunidades, o gradiente altitudinal parece se aplicar a comunidade fitotelmática, corroborando com os dados de Richardson (1999), embora não tenham sido estatisticamente significativos. O pico de riqueza de espécies em altitudes intermediárias, bem como um decréscimo na abundância dos organismos conforme aumenta a altitude, mostram como a altitude pode ser um modelador da biodiversidade, exibindo padrões semelhantes a diferentes organismos do macro e microcosmo.

Uma vez que as bromélias são plantas endêmicas de região Neotropical, com seu maior grau de diversidade e endemismo no Brasil, espera-se que estudos como estes mostrem, também, a importância da conservação dos remanescentes da Mata Atlântica. As bromélias são componentes vegetais abundantes deste bioma, e a preservação destas áreas podem garantir não só a existência das bromélias em si, mas da extensa diversidade inserida nos seus fitotelmos, bem como a diversidade de organismos deste bioma, que podem atuar como dispersores e agregadores da biodiversidade fitotelmática.

Como perspectivas futuras, espera-se que o conhecimento sobre a ocorrência de espécies em fitotelmos seja acrescida, desde análises morfológicas até sequenciamentos moleculares que permitam uma investigação de maior acurácia sobre a composição dos organismos, desde procariotos até metazoários. Além disso, estudos experimentais que permitam elucidar as relações *in situ* da bromélia com a comunidade acompanhante de suas cisternas, podem clarear o entendimento sobre os diferentes padrões da diversidade fitotelmática ocorrendo em espécies de bromélia, e em altitudes diferentes.