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MICROBIOLOGY

"Hitchhicking with invertebrates": two reports of epibiosis by peritrich ciliates on ostracods and hydrachnid mites in tanks of epiphytic bromeliads from south Brazil

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Abstract: Temporary waters are common environments found in physical and biological substrates. Among them, some bromeliads species are known to hold water in their tanks, in a habitat called phytotelmata. Phytotelmata serve as habitats for several organisms, from bacteria and protists to arthropods and anurans. Peritrich ciliates are often found as epibionts on aquatic invertebrates in these environments. Here, we report two cases of epibiosis involving *Lagenophrys* sp. attached to ostracods (*Elpidium* spp.) and *Rhabdostyla* sp. colonizing hydrachnid mites in the tanks of two bromeliad species. In our analysis, we measured the frequency of epibiosis considering the presence of both basibiont and epibiont in the samples. The results shown a significant difference between *Elpidium* sp. and *Lagenophrys* sp. compared to hydrachnid mites and *Rhabdostyla* sp. (87.5% and 19%, respectively), supported by the Kruskal-Walis test ($p = 0.0003$, Chi-square = 9.687). These reports are important since the knowledge of phytotelmata communities from tropical and subtropical areas is incipient, although it has been increasing over the last years. It also shows that epibiosis doesn't always represent a beneficial relationship. These two epibiosis systems found in bromeliad tanks raise questions about organism's dispersal throughout other phytotelmata and other temporary water habitats.

Key words: Bromeliads, Epibiosis, Peritrich ciliates, phoresy, temporary waters.

INTRODUCTION

Phytotelmata microhabitats harbor a high biodiversity and are models for natural experiments, receiving increasing interest by the scientific community (Teixeira et al. 2018). These microenvironments are model systems with a great diversity of organisms, where complex relationships (i.e., epibiosis) occur (Marino et al. 2011). In these environments, it is also possible to observe events of colonization, dispersion, competition, and prey-predator interactions (Siri et al. 2008). According to a scientometrics research by Teixeira et al. (2018), phytotelmata hold a high diversity of biological communities, although there are still few studies focusing on these microhabitats. The most representative plant families that form phytotelmata are Bromeliaceae, Poaceae, and Apiaceae. Global concerns such as climate change and habitat fragmentation have attracted the attention to these environments in the recent years since they are reservoirs of biodiversity.

Bromeliads are considered temporary environments since they allow water to accumulate for different periods, serving as model organisms for natural experiments in different ecological studies. Bromeliad leaves are arranged in rosettes and, at their bases, the storage of water and organic matter creates an environment suitable for several organisms. Organisms such as bacteria, protists, arthropods (insect larvae, crustaceans, mites), and frogs (Gofferdi et al. 2015, Teixeira et al. 2018) have been reported colonizing bromeliad tanks. The colonization of these environments seems to be complex, involving interconnected sequential events, such as dispersion, arrival, and establishment of the organisms. Maguire (1971, 1963) described three mechanisms of dispersal of organisms in isolated bodies of water: wind and rain (passive), flight (active) and phoresy (introduction by another species). Bromeliads, in a comparative approach, can represent "suspended lakes" in a forest matrix, comparing the colonization process of the tanks with those that take place on islands (Frank & Lounibos 1987).

Considering that bromeliads have more than 3,000 species, with different habitats and morphologies, the diversity of ciliates that inhabits these environments remains poorly studied and underestimated (Foissner et al. 2003). Most bromeliad species are restricted to the Neotropics, and this type of phytotelmata provides evidence for the endemicity and speciation of some ciliate species (Dunthorn et al. 2012). According to Foissner et al. (2003), two main categories of free-living ciliates inhabit bromeliad tanks: those that inhabit the mud and water column and those that live as epibionts attached to invertebrates. Peritrichia is a subclass of ciliates that include stalked and sedentary organisms, which may be solitary or colonial (Lynn 2008). These organisms are often observed as part of a relationship entitled epibiosis. This is an association between two organisms (epibiont-host or basibiont), and it is a common way of phoresy in nature (Cabral et al. 2010). In this way, ciliates can use other organisms as dispersing agents to colonize new environments.

In isolated bodies of water, it is required to evaluate how dispersion processes occur. Some examples of hyperphoresy available in bromeliad tank environments are ostracods and annelids using the body of frogs to disperse to other bromeliads, and mites using birds and bumblebees (Lopez et al. 1999, 2005, García-Franco et al. 2001, Guerra et al. 2010, Araújo et al. 2019, Moroti et al. 2019). Some of these invertebrates are often carrying peritrich ciliates with them. Phoresy studies involving peritrich ciliates, on the other hand, are rare. Two cases of loricate ciliates represented by the genus *Lagenophrys* attached to ostracod shells were recorded by Sabagh et al. (2011), Jankowsk & Yankosvsky (2014) and Mestre et al. (2019) in Rio de Janeiro (Brazil), St. Petersburg (Russia), Iberian Peninsula and Balearic Islands (SW Europe) respectively. A recent study conducted by Chatterjee et al. (2018) has identified more than 10 species of peritrich ciliates living in both halacarid and hydrachnid mites, without specific preferences to their hosts. Other studies focusing on epibiosis and phoretic interactions in bromeliads or temporary bodies of water remain scarce.

MATERIALS AND METHODS

During a fieldwork sampling bromeliad water across an altitudinal range (Malfatti et al. 2020), we observed two epibiotic relationships between ostracods and *Lagenophrys* sp., and mites and *Rhabdostyla* sp.. These relationships occurred in two different bromeliad species, in two different altitudes over a mountain range in Serra Geral, southern Brazil. The sampling sites were in Garapiá river (29° 30'' S 50°14' W) at 400 m above sea level (a.s.l.), and in RPPN Pró-Mata/

PUCRS (29° 29’ S 50° 21’ W), a private Protected Area owned by the Pontifícia Universidade Católica do Rio Grande do Sul, at 900m a.s.l.. Two sampling campaigns were carried out in each season: spring, summer, fall, and winter (total of 8 campaigns in each location), between October 2017 and September 2018. In both sites, bromeliad species in the genus *Vriesea* Gaudich. were chosen: *V. incurvata* was sampled in the Garapiá river, while *V. friburgensis* was sampled in Pró-Mata. We selected the bromeliad species based on their abundance in the study areas, and the presence of flower for correct identification.

The two bromeliad species were similar in size, in habit (both are epiphytes), and were at a maximum of 1.5m height above the ground. We sampled a total of 24 individuals from each species, three per campaign, randomly selected. In our original sample design, we collected fifteen milliliters of the central cistern water using a sterile Pasteur pipette and placed in Falcon tubes. We analyzed 8mL of *in vivo* samples to identify the species that composed the eukaryotic community, while the rest (7mL) were fixed in Lugol 10%. During the study period, we found the peritrich ciliate *Lagenophrys* sp. attached to specimens from the ostracod genus *Elpidium* in the tanks of *V. incurvata*. In *V. friburgensis*, we observed different species of Hydrachnidae mites carrying the peritrich genus *Rhabdostyla*. These epibiotic relationships were present in many samples analyzed and we estimated the frequency of their occurrence.

RESULTS

The *Lagenophrys* sp./*Elpidium* sp. epibiotic system occurred in 58.3% of all analyzed samples, whereas the *Rhabdostyla* sp./ Hydrachnidae mite relationship was observed in 16.7%. Ostracods carrying *Lagenophrys* sp. were present in all seasons, while *Rhabdostyla* sp. colonized mites during spring, summer, and winter. We also observed *Rhabdostyla* spp. as free-living individuals, occurring over debris and organic matter in our study. Lagenophryids has a higher prevalence on ostracod shells, with 5 to 6 individuals attached to each basibiont. Individuals of *Rhabdostyla* sp. were observed colonizing specially the legs of mites.

In our analysis, we measured the frequency of epibiosis considering the presence of both basibiont and epibiont in the samples. We tested if the frequency of these relationships were different, and their seasonal variance. The results shown a significant difference between *Elpidium* sp. and *Lagenophrys* sp. epibiosis than Hydrachnidae mites and *Rhabdostyla* sp. (87.5% and 19%, respectively), supported by the Kruskal-Wallis test (p = 0.0003, Chi-square = 9.687) (Table I).

This difference is also reflected troughout the seasons, where *Elpidium* sp. and *Lagenophrys* sp. occourred at all seasons, and had a higher frequency in the samples, varying from 83.3% to 100%. Hydrachnidae mites and *Rhabdostyla* sp. were present in spring, summer and winter (33.3%, 20% and 20%, respectively).

DISCUSSION

Our report supports a close association between ostracods and *Lagenophrys* sp.. We assume that ostracods are potential dispersers of *Lagenophrys* sp. between bromeliad tanks, and probably to other temporary pools, where they inhabit. One of the reasons may be the presence of the ostracod bivalve shell, which provides a hard protective substrate for the host, and a large area for epibiont attachment. Apparently, the epibiont load did not affect the swimming behavior of the ostracods, which could favor dispersion. Without movement impairment of the host, epibionts could be dispersed for

Table I. Total frequency (%) of both epibiosis systems and troughout the seasons.

Frequency of epibiosis (%)		
	***Elpidium* sp. and *Lagenophrys* sp.**	**Mite and *Rhabdostyla* sp.**
Spring	100	33.3
Summer	83.3	20
Autumn	83.3	0
Winter	100	20
Total	87.5	19
* considering the presence of both basibiont and epibiont in the samples.		

long distances, and even "hitchhike" when the ostracods are being transported by frogs, lizards, or snakes (Lopez et al. 1999). As for *Rhabdostyla* sp., even if the epibiont is affecting host movement, and this effect depends on the epibiont load, host and epibiont might be dispersed when carried by other animals (García-Franco et al. 2001, Guerra et al. 2010, Araújo et al. 2019, Moroti et al. 2019).

Some studies have related epibionts specificity to hosts at family, genus, and even species level (Cook & Chubb 1998, Nenninger 1948). The frequency of *Lagenophrys* sp. living on ostracod shells in our samples indicate a preference of the peritrich ciliate for this living substrate. Lagenophryids are well known as obligate symbionts of some crustaceans, predominantly in freshwater, occurring on the gills, legs or in the integument of their hosts (Corliss & Brough 1965). The majority of species have been reported as epibionts on amphipods, although cladocerans, ostracods, copepods, and isopods have also been reported as hosts (Kahl 1935, Shomay 1953, Clamp 1973).

According to Clamp (1973), *Lagenophrys* spp. filter their food by the currents created by respiratory or locomotory activities of the hosts, which reinforces the obligatory association these peritrichs have with their hosts. Shomay (1955) discussed that the restriction of epizoic ciliates of some crustaceans relates to the affinity of the hosts' exoskeletons with epibiont properties. According to Mayén-Estrada & Clamp (2016), lagenophryids are usually flattened along its oral-aboral axis, and attaches to surfaces with the base of the lorica, and it may be attracted by physical (thigmotactic) or chemical (chemotactic) signals. These signals may allow the epibiont to detect small differences in the exoskeletons of different crustaceans (Clamp 1973). Studies analyzing host attributes and areas for attachment considered feeding behavior (Fernandez-Leborans & Gabilondo 2006), protected areas (Fernandez-Leborans 2003), trophic differences (Clamp 2005), less active parts (Utz & Coats 2005), and availability of respiratory or filter feeding currents (Arndt et al. 2005). Considering their association with ostracods, the shells of *Elpidium* spp. seems to offer a suitable and secure surface to attach.

It is worth mentioning that *Elpidum* species are distributed mostly in temporary water environments (Little & Herbert 1996). Some reproductive characteristics of these species are adapted to the typical ephemerality of phytotelmata and similar habitats. To deal with the stressful conditions of these environments, both basibiont and epibiont may develop adaptative mechanisms of reproduction related to drought and wet periods (Foissner 2003, Halberg et al. 2013, Buosi et al. 2015). Studies relating their reproductive response to different seasons are needed to elucidate these questions.

Rhabdostyla spp. are extensively listed in the literature in epibiosis with different metazoan groups such as rotifers, copepods, mites, annelids, and even Diptera, Ephemeroptera, and Odonata larvae (Cabral et al. 2016, Chatterjee et al. 2018, Corbi et al. 2017, Dias et al. 2007). Despite being widely observed as epibionts, these peritrich ciliates are also often found as free-living forms in different habitats (Patterson 1992). Although there was a low frequency of this epibiotic relationship with mites, the colonization rate was high with a mean of four to six individuals per host. In this case, there was a clear impairment of the host's movement due to the heavy epibiont load. Effects of epibionts on the host movements was also reported by Henebry & Ridgeway (1979), where peritrich ciliates were found at any point on their host where they would not sustain damage from the organism's swimming and feeding activities. Epibiosis can also negatively affect basibionts by increasing weight and friction, decreasing flexibility, or shading basibionts from light and access to dissolved molecules (Wahl & Mark 1999). According to Corbi et al. (2017), the relationship is more beneficial to the epibiont since they can often improve their dispersal capability or reach nutrient-rich and more oxygenated spots.

Water mites (Hydrachnidae) present interesting biological and ecological aspects related to reproduction, feeding, and development. Both adults and deutonymphs are predators, sucking the preorally digested fluid or insect eggs (Böttger 1970, Proctor & Pitchard 1989, Smith & Cook 1991). They reproduce sexually, although there are cases of parthenogenesis (especially in phytotelmata habitats due to the stressful environments), which explains the unbalanced sex ratios of some assemblages (Baker 1991, Proctor 1996). Since they are active predators, epibiosis could cause friction in their displacement, affecting the host's survival. In our study, during the analyses of living samples, mites seemed to move slowly due to the epibiont load, which may explain the low frequency of the epibiosis with *Rhabdostyla* sp..

Kwet et al. (2010) published a guide with 56 species of amphibians from Pró-Mata and other areas of the mountain forests of Serra Geral of south Brazil. The bromeliads sampled in our study were inserted in Atlantic forests that harbod a great diversity of herpetofauna. Few examples of phoresy considering the environment of the bromeliads is ostracods and annelids using the body of frogs to disperse and to move to among bromeliads (Lopez et al. 1999, 2005). Sabagh and collaborators (2011) found that the anurans carrying ostracods has ciliates from the genus *Lagenophrys* sp. attached on their shells. We suggested that "hyperphoresy" may be occurring, where *Lagenophrys* can "hitchhike" with *Elpidium* ostracods, which in turn may be transported to other bromeliads by serpents and amphibians. Since mites and *Rhabdostyla* sp. had a weaker association, maybe hyperphoresy doesn't contribute to their dispersal.

We observed a higher prevalence of ostracods with *Lagenophrys* sp. during spring. Maybe there is a seasonal influence on this epibiosis related to flowering event of the bromeliads. Negrelle & Muraro (2006) found that the flowering peak period of *V. incurvata* occurs during spring. According to Araujo et al. (1994) the hummingbird species *Ramphodon naevius* is responsible for pollination in *V. incurvata* and other *Vriesea* species. Although phoretic relationships of ostracods is well documented with amphibians, these crustaceans could also "hitchhike" on birds in non-marine environments (Green & Figuerola 2005). In this case, the flowering event of *V. incurvata* during spring could indicate higher presence of pollinators visiting bromeliads, which may increase dispersion of *Elpidium* sp., leading to an increase in abundance during this season. Bromeliaceae is one of the few families of plants that are pollinated predominantly by birds rather than insects, and hummingbirds pollinate most species of this family (Smith & Downs 1974, Sick 1997). In this case, pollinators may be helping in the dispersion of ostracods and their epibionts across different bromeliad individuals.

According to Cook & Chub (1998), epibiosis can be a facultative, opportunistic, and non-specific relationship. Epibiosis has major effects on the species involved and on community structure and dynamics. Coevolution can be expected when this relationship leads to a specificity of both basibiont and epibiont, although current evidence suggests that many epibionts are generalists regarding the substratum they use (Wahl & Mark 1999). In nature, epibiosis have been studied for a long time, although there is a large gap in the knowledge about the colonization of zooplankton by epibionts in tropical and subtropical systems (Regali-Seleghim & Godinho 2004). In phytotelmata habitats, the knowledge of biodiversity is increasing and, consequently, more can be discovered about these relationships. In our study, the two epibiotic systems showed different intensities of association between the species involved.

This report focused on the association between invertebrate hosts and their epibionts, considering the obligate condition of the relationship and discussing the potential role of the hosts as dispersers of the ciliates. Results that pointed out a strong fluctuation and association between the frequency of epibionts and hosts, like *Elpidium* sp. and *Lagenophrys* sp., have indicated a well-established relationship. In these cases, the peritrich ciliate have a stable living substrate to attach and can have its dispersion linked to the phoresy of its hosts. The presence of an epibiont not always produce beneficial or neutral effects on its host. The epibiotic relationship between Hydrachnidae mites and *Rhabdostyla* sp. observed in this study could raise questions on how epibiotic relationships may bring negative effects to their hosts, affecting their capacity of dispersal and even survival, making this genus of peritrich ciliate a possible ectoparasite. This should be considered when studying the interactions between host-epibiont in any epibiotic relationship.

REFERENCES

ARAÚJO AC, FISCHER EA & SAZIMA M. 1994. Floração sequencial e polinização de três espécies de *Vriesea* (Bromeliaceae) na região de Juréia, sudeste do Brasil. Rev Bras Bot 17: 113-118.

ARAÚJO AP, BASTOS CM, SANTOS RVI, MOURA GJB, MELO-JUNIOR M & TINOCO MS. 2019. Novel records of phoresy among microcrustaceans and bromeliad treefrogs in the Atlantic Rainforest of Northeast Brazil. Herpetol Notes 12: 531-535.

ARNDT CE, FERNANDEZ-LEBORANS G, SEUTHE L, BERGE J & GULLIKSEN B. 2005. Ciliated epibionts on the Arctic sympagic amphipod *Gammarus wilkitzkii* as indicators for sympago-benthic coupling. Mar Biol 147: 643-652.

BAKER RA. 1991. Development and life strategies in mussel mites. In Schuster R & Murphy PW (Eds), The Acari: Reproduction, development and life history strategies. Chapman and Hall, London, p. 65-73.

BÖTTGER K. 1970. Die Ernährungsweise der Wassaremilben (Hydrachnellae, Acari). Int Rev Ges Hydrobiol 55(6): 895-912.

BUOSI PRB, CABRAL AF, UTZ LRP, LUDGERO CG, VIEIRA LCG & VELHO LFM. 2015. Effects of Seasonality and Dispersal on the Ciliate Community Inhabiting Bromeliad phytotelmata in Riparian Vegetation of a Large Tropical River. J Eukaryot Microbiol 62: 737-749.

CABRAL AF, DIAS RJP, UTZ LRP, ALVES RG & D'AGOSTO M. 2010. Spatial and temporal occurrence of *Rhabdostyla* cf. *chironomi* Kahl, 1933 (Ciliophora, Peritrichia) as an epibiont on chironomid larvae in a lotic system in the neotropics. Hydrobiologia 644: 351-359.

CABRAL AF, UTZ LRP & VELHO LFM. 2016. First report of an epibiotic relationship between ciliates and planktonic copepods in a Brazilian floodplain. Rev Bras Zoociênc 17(1): 124-131.

CHATTERJEE T, DOVGAL I, PEŠIĆ V & ZAWAL A. 2018. A checklist of epibiont suctorian and peritrich ciliates (Ciliophora) on halacarid and hydrachnid mites (Acari: Halacaridae & Hydrachnidia). Zootaxa 4457(3): 415-430.

CLAMP JC. 1973. Observations on the host-symbiont relationships of *Lagenophrys lunatus* Imamura. J Protozool 20: 558-651.

CLAMP JC. 2005. Redescription of *Lagenophrys maxillaris* (Jankowski, 1993) (Ciliophora, Peritrichia, Lagenophryidae), an ectosymbiont of marine amphipods. Jour Euk Microbiol 52: 38-43.

COOK JA & CHUBB JC. 1998. Epibionts of *Asellus aquaticus* (L.) (Crustacea, Isopoda): an SEM study. Freshw Biol 39: 423-438.

CORBI JJ, ABRAHÃO DP, MELLO JLS & GORNI GR. 2017. Record of Epibiont ciliates (Ciliophora: Peritrichia) living on larvae of Odonata from Brazil. Braz J Biol 77(2): 417-419.

CORLISS JO & BROUGH IMA. 1965. New Species of *Lagenophrys* (Ciliata: Peritrichida) from the Jamaican crab *Metopaulias depressus*. Trans Amer Micr Soc 84(1): 73-80.

DIAS RJP, CABRAL AF, STEPHAN NNC, MARTINS RT, SILVA-NETO ID, ALVES RG & D'AGOSTO M. 2007. Record of *Rhabdostyla chironomi* Kahl, 1933 (Ciliophora, Peritrichia) Epibiont on Chironomidae larvae (Diptera, Chironomidae) in a lotic system in Brazil. Braz J Biol 67(4): 783-785.

DUNTHORN M, STOECK T, WOLF K, BREINER HW & FOISSNER W. 2012. Diversity and endemism of ciliates inhabitating neotropical phytotelmata. Syst and Biod 10: 195-205.

FERNANDEZ-LEBORANS G. 2003. Ciliate-decapod epibiosis in two areas of the north-west Mediterranean coast. J Nat Hist 37: 1655-1678.

FERNANDEZ-LEBORANS G & GABILONDO R. 2006. Taxonomy and distribution of the hydrozoan and protozoan epibionts on *Pagurus bernhardus* (Linnaeus, 1758) (Crustacea, Decapoda) from Scotland. Acta Zoologica (Stockholm) 87: 33-48.

FOISSNER W. 2003. Morphology and ontogenesis of *Lambornella trichoglossa* nov. spec. a new tetrahymenid ciliate (Protozoa,Ciliophora) from Brasilian tank bromeliads. Eur J Protistol 39: 63-82.

FOISSNER W, STRUDER-KYPKE M, VAN DER STAAY GWM, MOON-VAN DER STAAY SY & HACKSTEIN JHP. 2003. Endemic ciliates (Protozoa, Ciliophora) from brazilian tank bromeliads (Bromeliaceae): a combined morphological, molecular and ecological study. Eur J Protistol 39: 365-372.

FRANK JH & LOUNIBUS LP. 1987. Phytotelmata: swamps or islands? Fla Entomol 70: 14-20.

GARCÍA-FRANCO JG, BURGOA DM & PÉREZ TM. 2001. Hummingbird flower mites and *Tillandsia* spp. (Bromeliaceae): polyphagy in a cloud forest of Veracruz, Mexico. Biotropica 33: 538-544.

GOFFERDI S, JANG G & HAROON MF. 2015. Transcriptomics in the tropics: Total RNA-based profiling of Costa Rican bromeliad-associated communities. CSBJ J 13: 18-23.

GREEN AJ & FIGUEROLA J. 2005. Recent advances in the study of long-distance dispersal of aquatic invertebrates via birds. Divers Distrib 11: 149-156.

GUERRA TJ, ROMERO GQ, COSTA AC & BENSON WW. 2010. Phoretic dispersal on bumblebees by bromeliad flower mites (Mesostigmata, Melicharidae). Insectes Soc 59(1): 11-16.

HALBERG KA, JORGENSEN A & MOBJERG N. 2013. Dissecation tolerance in the tardigrade *Richtersius coronifer* relies on muscle mediated structural reorganization. PLoS ONE 8: e85091.

HENEBRY MS & RIDGEWAY BT. 1979. Epizoic ciliated protozoa of planktonic copepods and cladocerans and their possible use as indicators of organic pollution. Trans Am Microsc Soc 98: 495-508.

JANKOWSK AW & YANKOVSKY AB. 2014. *Tokophrya sibirica* sp. nov. (Ciliophora: Acinetida), a symbiont of freshwater ostracods in Irkutsk Province. Zoosyst Ross 23(2): 174-177.

KAHL A. 1935. Urtiere oder Protozoa. I: Wimpertiere oder Ciliata (Infusoria). 4. Peritricha and Chonotricha. Tierwelt Dtl 30: 651-886.

KWET A, LINGNAU R & DI BERNARDO M. 2010. Pró-Mata: Anfíbios da Serra Gaúcha, Sul do Brasil - Amphibien der Serra Gaúcha, Südbrasilien - Amphibians of the Serra Gaúcha, South of Brazil. 2nd Edition, revised and enlarged; Brasilien-Zentrum de Universität Tübingen, Tübingen, Germany, and EDIPUCRS, Porto Alegre, Brazil, 148 p.

LITTLE TJ & HEBERT PDN. 1996. Endemism and ecological islands: the ostracods from Jamaican bromeliads. Freshw Biol 36: 327-338.

LOPEZ LCS, FILIZOLA B, DEISS I & RIOS RI. 2005. Phoretic behaviour of bromeliad annelids (*Dero*) and ostracods

(*Elpidium*) using frogs and lizards as dispersal vectors. Hydrobiologia 549: 15-22.

LOPEZ LCS, RODRIGUES PJF & RIOS RI. 1999. Frogs and snakes as phoretic dispersal agents of bromeliad ostracods (Limnocytheridae: *Elpidium*) and annelids (Naididae: *Dero*). Biotropica 31: 705-708.

LYNN DH. 2008. The Ciliated Protozoa. Characterization, Classification, and Guide to the Literature, 3rd ed., Springer, Dordrecht, 605 p.

MAGUIRE BJ. 1963. The Passive Dispersal of Small Aquatic Organisms and their Colonization of Isolated Bodies. Ecol Monogr 33: 85-161.

MAGUIRE BJ. 1971. Phytotelmata: Biota and Community Structure Determination in Plant-Held Waters. Annu Rev Ecol Evol Syst 2: 439-464.

MALFATTI E, FERREIRA PM & UTZ LRP. 2020. Eukaryotic Communities in Bromeliad Phytotelmata: How Do They Respond to Altitudinal Differences? Diversity 12: 326-340.

MARINO NAC, GUARIENTO RD, DIB V, AZEVEDO FD & FARJALLA VF. 2011. Habitat size determine algae biomass in tank-bromeliads. Hydrobiologia 678(1): 191-199.

MAYÉN-ESTRADA & CLAMP JC. 2016. An annotated checklist of species in the family Lagenophryidae (Ciliophora, Oligohymenophorea, Peritrichia), With a brief review of their taxonomy, morphology, and biogeography. Zootaxa 4132(4): 451-492.

MESTRE A, POULIN R, HOLT RD, BARFIELD M, CLAMP JC, FERNANDEZ-LEBORANS G & MESQUITA-JOANES F. 2019. The interplay of nested biotic interactions and the abiotic environment regulates populations of a hypersymbiont. J Anim Ecol 88: 1998-2010.

MOROTI MT, MUSCAT E, PEDROZO M, MACHADO IF, SABAGH LT & SANTANA DJ. 2019. Interaction between ostracods and anurans: a review and new records in Brazil. Phyllomedusa 18(2): 269-275.

NEGRELLE RRB & MURARO D. 2006. Aspectos fenológicos e reprodutivos de *Vriesea incurvata* Gaudich (Bromeliaceae). Acta Sci Biol Sci 28: 95-102.

NENNINGER U. 1948. Die Peritrichen der Umgebung von Erlangen mit besonderer Berücksichtigung ihrer Wirtsspezifität. Zoologische Jahrbuecher. Zool Jahrb Abt Syst Geog Biol 77: 169-266.

PATTERSON DJ. 1992. Free-Living Freshwater Protozoa: A Color Guide. Wolfe Publishing, 224 p.

PROCTOR H. 1996. Sex-ratios and chromosomes in water mites (Hydracarina). Acaralogy IX, Proceedings, Vol. 1. Ohio Biological Survey, Columbus, p. 441-445.

PROCTOR HC & PRITCHARD G. 1989. Neglected predators: water mites (Acari: Parasitengona: Hydrachnellae) in freshwater communities. J N Amer Benthol Soc 8(1): 100-111.

REGALI-SELEGHIM MH & GODINHO MJL. 2004. Peritrich epibiont protozoans in the zooplankton of a subtropical shallow aquatic ecosystem (Monjolinho Reservoir, São Carlos, Brazil). J Plankton Res 26: 501-508.

SABAGH LT, ROCHA CFD, DIAS RJP & BRANCO CWC. 2011. News records of phoresy and hyperphoresy among treefrogs, ostracods, and ciliates in bromeliad of Atlantic forest. Biodivers Conserv 20: 1837-1841.

SHOMAY D. 1953. The occurrence of the genus *Lagenophrys* Stein, 1852 (Ciliata; Peritricha) in North America. Proc Soc Protozool 4: 19-20.

SHOMAY D. 1955. A contribution to the morphology, taxonomy, and bionomics of the epizoic peritrichous ciliate *Lagenophrys labiata* Stokes, 1887. Doctoral Dissertation, U. of Illinois. University Microfilm #11536.

SICK H. 1997. Ornitologia brasileira. Rio de Janeiro: Nova Fronteira, 862 p.

SIRI A, DONATO M & PAGGI AC. 2008. New phytotelmic habitat of *Metricnemus eryngiotelmatus* (Diptera: Chironomidae). Revista de la Sociedad Entomológica 67(3-4): 113-115.

SMITH IM & COOK DR. 1991. Water Mites. In: Thorp JH and Covich AP (Eds). Ecology and Classification of North American Freshwater Invertebrates, Academic Press, San Diego, p. 523-592.

SMITH LB & DOWNS RJ. 1974. Bromeliaceae 1: Pitcairnordiae - Flora Neotropica. New York: Hafner 14: 40-64.

TEIXEIRA AP, SILVA PFRS, SOUZA JPF, ALVES NL, GUIMARÃES A & CARNEIRO FM. 2018. Trends in the scientific production on aquatic microhabitats phytotelmata: a scientometric study. Acta Sci Biol Sci 40: e40994.

UTZ LRP & COATS DW. 2005. Spatial and temporal patterns in the occurrence of peritrich ciliates as epibionts on calanoid copepods in the Chesapeake Bay, USA. J Eukaryot Microbiol 52: 236-244.

WAHL M & MARK O. 1999. The predominantly facultative nature of epibiosis: experimental and observational evidence. Mar Ecol Prog Ser 187: 59-66.

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