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BRIEF COMMUNICATION

News records of phoresy and hyperphoresy among treefrogs, ostracods, and ciliates in bromeliad of Atlantic forest

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Abstract The bromeliad habitat contributes to a high biodiversity and we recorded three treefrog species as new phoretic agents of ostracods, and a first case of hyperphoresy among treefrogs, ostracods and ciliates, in these habitats of Atlantic Forest. Densities of ciliates and ostracods showed significant relationships suggesting the importance of hyperphoresy for ciliate dispersion.

Keywords *Elpidium* · *Lagenophrys* · Phytotelmata · *Scinax* · Symbiosis

Most bromeliad species are able to amplify and sustain the biodiversity due to water storage in a tank formed by their tightly-overlapping leaf bases. Into these tanks, many aquatic organisms live in the water retained (phytotelm) and for them, the bromeliads function as ecological islands (Frank and Lounibos 1987; Little and Hebert 1996) in the sense that the bromeliad tank is a small unit of water surrounded by terrestrial environment. For animals that have their all life cycle inside the water retained in the bromeliad tank, this relative isolation constitutes a considerable restriction for dispersion and colonization. To disperse, some of these organisms need to attach to the body of other animals. Phoresy (from the Greek *phórésis*) refers in ecology to interspecific relationships in which one organism (the phoretic) attaches to the body of another (the host) for the implied purpose of dispersal (Houck and O'Connor 1991). One of the few examples of phoresy available regarding the environment of the bromeliads and their associated forms of life is

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that of ostracods and annelids using the body of frogs to disperse and to move to among bromeliads (Lopez et al. 1999, 2005) and with mites using birds (García-Franco et al. 2001) and bumblebees (Guerra et al. 2010). Additionally, hyperphoresy is a rarely observed phenomenon, in which an animal being phoretically transported carries in turn, another phoretic animal on its own body (Szymkowiak et al. 2007). These are two forms of ecological interactions that remain still relatively poorly known and recorded.

Here we present three new records of phoresy among ostracods and treefrogs (Hylidae family) in bromeliads at the Rio de Janeiro State, Brazil, and two records of peritrich ciliates with hyperphoresy on ostracods and treefrogs (Table 1).

During fieldwork in the restinga habitat of Grumari (23° 03′ S–43° 32′ W), Rio de Janeiro municipality we found one individual of the treefrog *Hypsiboas albomarginatus* on a leaf of the bromeliad *Neoregelia pascoaliana*. Smith with an ostracod attached to its leg (Fig. 1a). According to Peixoto (1995), *H. albomarginatus* is a bromelicolous treefrog, using the bromeliad only as a shelter.

During fieldwork at the coastal Inselberg Costão de Itacoariara (22° 58′ S–43° 01′ W) at Parque Estadual da Serra da Tiririca–Niterói municipality, 20 individuals of *Scinax littoreus* also had ostracods of the genus *Elpidium* (Limnocytheridae) (Fig. 1b) on their bodies. Similarly at the coastal Inselberg Natural Monument of Morro da Urca and Sugar Loaf (22° 57′ S–43° 09′ W), Rio de Janeiro municipality we recorded 13 individuals of the treefrog *S. perpusillus* having phoretic agents of the ostracod of the genus *Elpidium* (Fig. 1c) on their bodies also. The records occurred in months of the dry (July and August) and of the rainy (December and January) seasons in the same bromeliad species–*Alcantarea glaziouana*. Peixoto (1995) classified *S. littoreus* and *S. perpusillus* as bromeligenous–species that have all their life cycle associated with bromeliads. Bromeligenous frogs supposedly constitute more effective agents for phoretic aquatic biota living exclusively in the water phytotelm compared to bromelicolous frogs that use bromeliads only as shelter. Additionally, attached on ostracod valves as epibionts, we found sessile ciliates of the genus *Lagenophrys* (Fig. 1 d–f). This peritrich protozoan is a cosmopolitan and loricate ciliate, adapted to living as ectosymbiont of a wide variety of crustaceans mainly in freshwater ecosystems (Mayén-Estrada and Aladro-Lubel 2007). They are stalked and secrete a lorica as a protective envelope around the body and apparently depends on currents created by respiratory or locomotory activities of the host to bring its particulate food supply (Clamp 1973, 2005). Members of this genus have skeletal plates around the oral opening, and these are clearly recognizable also in our species.

This is the first record of a Lagenophryidae ciliate attached to ostracods in bromeliad habitat. Corliss and Brough (1965) recorded for the first time a species of *Lagenophrys* in tank bromeliads attached to crabs in Jamaica. There are about 60 ciliate species recorded for bromelian tanks (Esteves and Silva-Neto 1996; Foissner et al. 2003, 2009), but many more can be expected because the tanks are generally poorly explored (Foissner et al.

Table 1 New records of phoresy and hiperphoresy among treefrogs, ostracods, and ciliates in bromeliad habitat of Atlantic Forest, Rio de Janeiro State–Brazil

Treefrog species	Bromeliad species	Ostracod	Ciliate	Location
Hypsiboas albomarginatus	*Neoregelia pascoaliana*	*Elpidium*	–	Grumari, Rio de Janeiro
Scinax littoreus	*Alcantarea glaziouana*	*Elpidium*	*Lagenophrys*	Itacoariara, Niterói
Scinax perpusillus	*Alcantarea glaziouana*	*Elpidium*	*Lagenophrys*	Sugar loaf, Rio de Janeiro

– Not examined

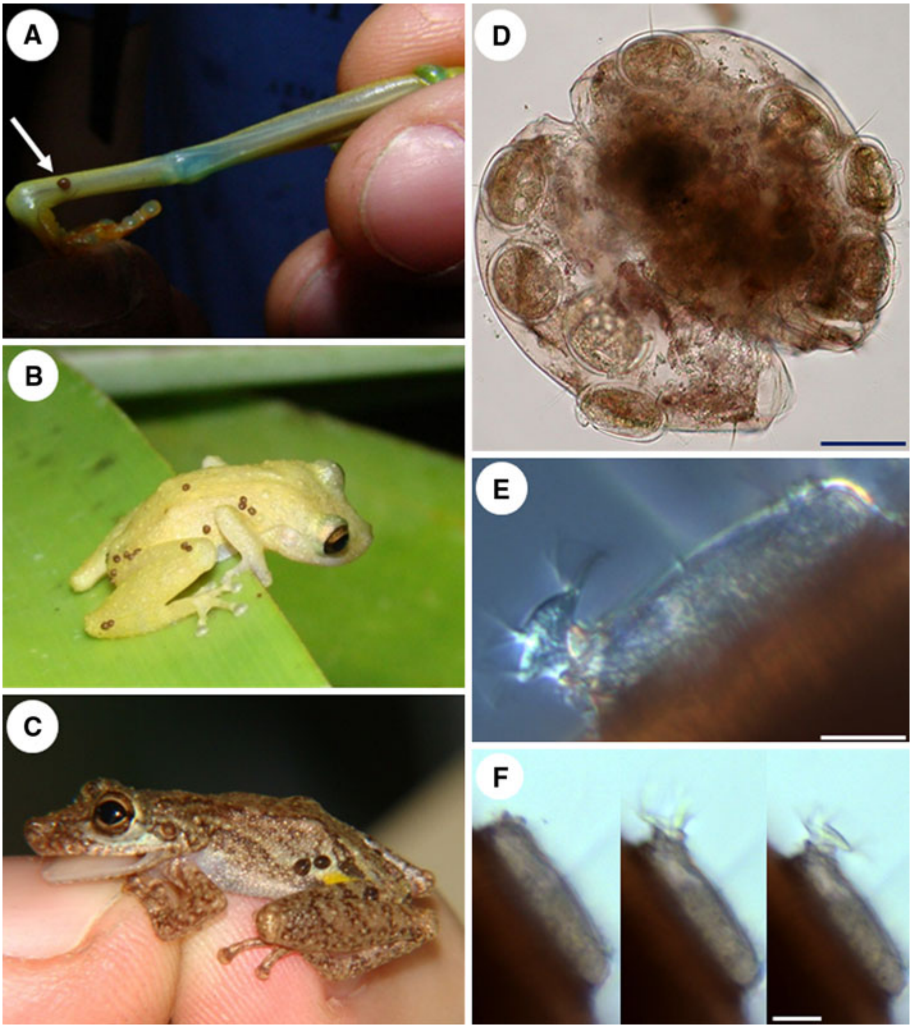

Fig. 1 Phoresy among ostracods and treefrogs, and hyperphoresy among ciliates, ostracods and treefrogs in bromeliads of Atlantic Forest, Rio de Janeiro State, Brazil. **a–c** Ostracod attached on treefrogs in Brazilian bromeliad habitats. **a** *Hypsiboas albomarginatus* at restinga of Grumari, Rio de Janeiro. **b** *Scinax littoreus* at Costão de Itacoariara, Niteroi. **c** *Scinax perpusillus* at Natural Monument of Morro da Urca and sugar loaf, Rio de Janeiro. **d–f** Light micrographs of *Lagenophrys* sp. attached to the ostracod *Elpidium* at the Natural Monument of Morro da Urca and sugar loaf, Rio de Janeiro State, Brazil. **d** At least eight *Lagenophrys* on ostracod. **e** Extended individual of *Lagenophrys* sp. attached to *Elpidium*. **f** The behaviour of *Lagenophrys* sp. coming out of the lorica. *Scale bars* (**d**) 70 µm, (**e**, **f**) 20 µm

2008). According to Foissner et al. (2003) is a common sense that the diverse and compartmentalized bromelian tank ecosystem will host hundreds, perhaps thousands of novel ciliates species. A detailed morphological study of the species, including also molecular analyses, will be made available soon.

Lagenophrys peritrichs were attached to ostracod valves, which in turn were attached on the bodies of the individuals of the two treefrog species of *Scinax*. This can be related as a case of hyperphoresy, with the treefrog dispersing both the ostracods and the *Lagenophrys*. The hyperphoresy probably is involuntary, but seems to be an important strategy for dispersal of the protozoa among bromeliads.

To investigate the relationship between the densities of ostracods (*Elpidium*) and ciliates (*Lagenophrys*) in bromeliad phytotelm we sampled the water stored inside the tank of 14 bromeliads at the two studied Inselbergs areas. The relationship between *Elpidium* density and *Lagenophrys* density were statistically significant ($F_{\text{Itacoatiara}} = 36.23$; $R^2_{\text{Itacoatiara}} = 0.75$; $p_{\text{Itacoatiara}} < 0.0001$; $df_{\text{Itacoatiara}} = 12/F_{\text{Sugar-loaf}} = 7.93$; $R^2_{\text{Sugar-loaf}} = 0.40$; $p_{\text{Sugar-loaf}} = 0.016$; $df_{\text{Sugar-loaf}} = 12$) suggesting evidence of the importance of hyperphoresy for protozoa dispersion, specially at Itacoatiara.

Our observation suggested that the attachment on frogs by ostracods is made through the closing of its valves having skin of frog in the middle of these valves. In terms of phoresy, a few other frog species have also been recorded as phoretic agents of ostracods (genus *Elpidium* also) and annelids: *Aparasphenodon brunoi, Hypsiboas semilineatus*, *Aplastodiscus arildae*, *Xenohyla truncata, Flectonotus goeldii* (Lopez et al. 1999, 2005), and *Sphaenorhynchus* aff. *surdus* (Colombo et al. 2008). Frogs are also important vectors and dispersers of seeds in bromeliad environment with the treefrog *Xenohyla truncata* eating fruits and dispersing seeds of the shrub *Erythroxylum ovalifolium* (Fialho 1990), and also for aquatic invertebrates by endozoochory with the taxa *Xenopus laevis* and Copepoda, Acari, Anostraca, and Spinicaudata in a rock pool habitat (Vanschoenwinkel et al. 2008).

Records of phoresy with peritrich ciliates are common. They live attached to a variety of species of aquatic metazoans, including various groups of freshwater invertebrates such as: rotifers, tardigrades, crustaceans, annelid worms, insect larvae and molluscs (Cabral et al. 2010). Foissner et al. (2003) found undescribed peritrichs attached to oligochaetes and mosquito larvae in bromeliad habitats from the Dominican Republic, Ecuador, and Brazil. Hyperphoresy has been reported for mites (Houck and O'Connor 1991; Szymkowiak et al. 2007), but rarely for other animal taxa.

In conclusion, this study brings four new records: (1) the first record of phoresy involving frogs in the genus *Scinax* as phoretic agents; (2) the first record of phoresy having the three reported frog species (*S. perpusillus, S. littoreus*, and *Hypsiboas albomarginatus*) as phoretic agents of Ostracoda; (3) the first record of *Lagenophrys* attached to ostracods in bromeliad habitat; and (4) the first record of hyperphoresy involving simultaneously ciliates, ostracods and treefrogs. These new records can contribute to the understanding of these interesting and poorly documented phenomenon and confirm the importance of amphibians in maintain the biodiversity of tank bromeliad microcosms.

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