UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

POSGRADO EN CIENCIAS BIOLÓGICAS

FACULTAD DE CIENCIAS

DIVERSIDAD DE CILIADOS (ALVEOLATA: CILIOPHORA) EN BROMELIAS DE LA REGIÓN NEOTROPICAL. TAXONOMÍA, ECOLOGÍA Y DISTRIBUCIÓN

TESIS

QUE PARA OPTAR POR EL GRADO DE:

DOCTOR EN CIENCIAS

PRESENTA:

CARLOS ALBERTO DURÁN RAMÍREZ

TUTOR(A) PRINCIPAL DE TESIS: DRA. ROSAURA MAYÉN ESTRADA
FACULTAD DE CIENCIAS, UNAM
COMITÉ TUTOR: DR. ALFONSO LUGO VÁZQUEZ
FES IZTACALA, UNAM
DR. JORGE CIROS PÉREZ
FES IZTACALA, UNAM

CIUDAD UNIVERSITARIA, CD. MX., MARZO, 2021

UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

POSGRADO EN CIENCIAS BIOLÓGICAS

FACULTAD DE CIENCIAS

DIVERSIDAD DE CILIADOS (ALVEOLATA: CILIOPHORA) EN BROMELIAS DE LA REGIÓN NEOTROPICAL. TAXONOMÍA, ECOLOGÍA Y DISTRIBUCIÓN

TESIS

QUE PARA OPTAR POR EL GRADO DE:

DOCTOR EN CIENCIAS

PRESENTA:

CARLOS ALBERTO DURÁN RAMÍREZ

TUTOR(A) PRINCIPAL DE TESIS: DRA. ROSAURA MAYÉN ESTRADA
FACULTAD DE CIENCIAS, UNAM
COMITÉ TUTOR: DR. ALFONSO LUGO VÁZQUEZ
FES IZTACALA, UNAM
DR. JORGE CIROS PÉREZ
FES IZTACALA, UNAM

CIUDAD UNIVERSITARIA, CD. MX., 2021

COORDINACIÓN DEL POSGRADO EN CIENCIAS BIOLÓGICAS

FACULTAD DE CIENCIAS

OFICIO CPCB/150/2021

ASUNTO: Oficio de Jurado

M. en C. Ivonne Ramírez Wence
Directora General de Administración Escolar, UNAM
P r e s e n t e

Me permito informar a usted que, en la reunión virtual del Comité Académico del Posgrado en Ciencias Biológicas, celebrada el día **29 de junio de 2020** se aprobó el siguiente jurado para el examen de grado de **DOCTOR EN CIENCIAS** del estudiante **DURÁN RAMÍREZ CARLOS ALBERTO** con número de cuenta **300630866** con la tesis titulada **"Diversidad de ciliados (Alveolata: Ciliophora) en bromelias de la región neotropical. Taxonomía, ecología y distribución",** realizada bajo la dirección de la **DRA. ROSAURA MAYEN ESTRADA,** quedando integrado de la siguiente manera:

Presidente:	DRA. LAURA ROBERTA PINTO UTZ
Vocal:	DR. ENRIQUE ARTURO CANTORAL URIZA
Secretario:	DR. ALFONSO LUGO VÁZQUEZ
Suplente:	DR. PABLO QUINTELA ALONSO
Suplente:	DR. ARMANDO AGUIRRE JAIMES

Sin otro particular, me es grato enviarle un cordial saludo.

A T E N T A M E N T E
"POR MI RAZA HABLARÁ EL ESPÍRITU"
Cd. Universitaria, Cd. Mx., a 24 de febrero de 2021

COORDINADOR DEL PROGRAMA

DR. ADOLFO GERARDO NAVARRO SIGÜENZA

POSGRADO EN CIENCIAS BIOLOGICAS
COORDINACIÓN

AGRADECIMIENTOS

Institucionales

Agradezco al Posgrado en Ciencias Biológicas de la Universidad Nacional Autónoma de México, que me otorgó la oportunidad y las facilidades para la realización de mis estudios de Doctorado en el período comprendido de 2016 a 2019. Gracias a mi tan amada UNAM¡, por ser una de las instituciones más importantes para este país y que me permite poner en manos del pueblo el presente trabajo.

Agradezco al Consejo Nacional de Ciencia y Tecnología (CONACYT) por otorgarme la beca 224627 sin la cual no habría sido posible la realización de esta tesis. Quiero agradecer también a mi institución de adscripción, la Facultad de Ciencias, lugar en el que he pasado días completos entregándome de lleno a una de mis grandes pasiones en la vida: la biología.

Agradezco con un profundo cariño a mi Asesora de Doctorado, la Dra. Rosaura Mayén-Estrada del Laboratorio de Protozoología de la Facultad de Ciencias, UNAM por su apoyo y enseñanzas a lo largo de estos años, su ayuda para realizar mis salidas de campo, por poner a mi disposición todas las facilidades en acceder a los recursos del laboratorio, así como su dedicación permanente para lograr la culminación de esta tesis. De la misma forma, por inculcar en mí el rigor indispensable en un trabajo científico y sobre todo por darme la valiosa oportunidad de aprender a través de múltiples colaboraciones al formar parte de un equipo de trabajo entrañable. Gracias infinitas Rosaura.

Quedo profundamente agradecido por el apoyo, consejos, comprensión y cordialidad permanente de mi Comité Tutor, conformado por el Dr. Alfonso Lugo Vázquez y el Dr. Jorge Ciros Pérez, ambos de la Facultad de Estudios Superiores-Iztacala, UNAM.

Personales

Quiero agradecer por las sugerencias y su tiempo invertido para la revisión de esta tesis a mi jurado: Dra. Laura R. Utz de la Pontificia Universidade Católica do Rio Grande do Sul (PUCRS), al Dr. Enrique A. Cantoral-Uriza de la Unidad Multidisciplinaria de Docencia e Investigación, de la Facultad de Ciencias-Campus Juriquilla, UNAM, al Dr. Armando Aguirre-Jaimes del Instituto de Ecología, A. C. y al Dr. Pablo Quintela-Alonso de la Universidad Complutense de Madrid.

Por su apoyo y autorización, agradezco al personal de la Estación de Biología Chamela, del Instituto de Biología de la UNAM, al Sr. H. Medina, propietario del Área de Conservación Forestal El Tegolome, al Comisariado de Bienes Comunales y Ejidales del Municipio de Santa Catarina Ixtepeji, Oaxaca, al Sr. James Callaghan, propietario de la Reserva Biocultural Kaxil Kiuic, y a la comunidad de Tziscao en Chiapas. A todos ellos gracias por el apoyo prestado para el trabajo de campo.

Expreso mi agradecimiento al personal del Laboratorio de Microcine de la Facultad de Ciencias, UNAM, por el apoyo en la obtención de material microfotográfico por parte de la M. en F. P. Ana I. Bieler A. y del M. en C. Alejandro Martínez-Mena (q.e.p.d) cuyas espléndidas imágenes están publicadas en los artículos científicos derivados del presente trabajo de tesis. Agradezco la ayuda para la verificación taxonómica de las especies de bromelias al Dr. Adolfo Espejo-Serna de la UAM-Iztapalapa. También agradezco al Dr. Ricardo Mariño por su apoyo en la consecución de algunas publicaciones digitales sin ser menos importante el apoyo indirecto que ha representado la plataforma puesta a disposición por A. Elbakyan para poder acceder a la literatura de manera libre.

Quedo en deuda con mis exalumnos, la Biól. Diana L. Fuentes, Biól. Abelardo Aguilar, Biol. Erick Juárez y Pas. Biol. Luis A. Hurtado, por todas las horas de amistoso apoyo prestadas para el procesamiento de muestras, bases de datos y realización de técnicas de laboratorio. De la misma forma, me siento agradecido por el apoyo otorgado por el Dr. Jair Morales, Biól. Gustavo Tovar y la Biól. Polenka Torres para llevar a cabo los distintos análisis estadísticos.

No me alcanzarían las palabras ni las ideas para hacerles saber a mis padres que sin su amor, apoyo, comprensión, y sacrificio, culminar esta etapa de mi vida habría sido muy difícil. Muchos de los anhelos de nuestros padres se ven realizados en los logros de sus hijos y por ello, este logro les pertenece en buena parte a ellos. Agradezco también con un profundo cariño y respeto a la Familia Castillo Lima, por todas las cosas que nos han llevado en esta vida a estar unidos, por el apoyo y cariño invaluable que me han dado todo este tiempo y por hacerme sentir siempre parte de ellos. Los quiero mucho.

Esta etapa definitivamente no hubiera sido ni tan divertida ni tan significativa sin la amistad de mis compañeros del Laboratorio de Protozoología: Mireya, Daniel, Jorge, Jazmín, Gerardo, Víctor y Erandeni. Con todos ustedes tengo recuerdos que perdurarán por siempre en la memoria del ‘Sr. D’. Gracias por su compañía, ayuda en campo, ayuda en laboratorio, por ser hombro para llorar, confidentes, cómplices, por ser apasionados de los protistas y por estar allí aguantándome en mis momentos difíciles que fueron muchos. Todos ustedes son personas especiales en esta historia.

A la memoria de ***Alberto Eliezer Castillo Lima***
por ser parte de mi alma

mis abuelos Ana, Chayo, Rafael y Manuel
por ser parte de mi sangre

Margarita Reyes Santos
por ser parte de esta historia

ÍNDICE

RESUMEN

Las bromelias cuya morfología permite la formación de una fitotelma, constituyen un hábitat donde se establecen comunidades de ciliados. El objetivo de la presente tesis fue registrar la riqueza específica y determinar la influencia de algunas variables ambientales sobre la comunidad de ciliados que habitan en bromelias epífitas y terrestres en diferentes tipos de vegetación de la Región Neotropical de México, durante los años 2014 a 2016, así como realizar una compilación de las especies registradas en las bromelias del resto del Neotrópico. Para cumplir con estos objetivos, se recolectaron muestras de 189 plantas. Como resultados, se presentan datos del registro de 48 especies de ciliados en 27 especies de bromelias presentes en cinco tipos de vegetación y algunos agroecosistemas cafetaleros en los estados de Chiapas, Hidalgo, Jalisco, Oaxaca, Puebla, Veracruz y Yucatán, México. Se obtuvo que en más del 95% de las plantas analizadas se registró al menos una especie de ciliado, siendo ocho especies nuevos registros de ciliados para México. Los resultados obtenidos reflejaron que el mayor número de especies de ciliados se registraron en las bromelias del bosque tropical caducifolio de la Reserva de la Biósfera Chamela Cuixmala, Jalisco, durante la temporada húmeda de los años 2015 y 2016, principalmente en bromelias que no son tipo tanque o que poseen fitotelmata poco desarrollada como *Bromelia karatas* y *Tillandsia makoyana* donde se destacó la presencia de las formas libre nadadoras de ciliados, y el resto fueron formas sésiles pertenecientes a la subclase Peritrichia. Las especies *Drepanomonas revoluta*, *Glaucomides bromelicola*, *Leptopharynx bromeliophilus* y *Tetrahymena* sp. fueron las más frecuentes que se registraron en el estudio. Se determinaron algunos aspectos ecológicos sobre la comunidad de ciliados en distintas especies de bromelias a lo largo de un gradiente de elevación con fragmentos de bosque de pino, mesófilo de montaña, tropical subcaducifolio y agroecosistemas cafetaleros del centro de Veracruz. Se observó que las comunidades de ciliados tuvieron una composición diferente de acuerdo al tipo de vegetación, y junto con la altitud sobre el nivel del mar y la temperatura del agua en las bromelias, constituyeron los tres principales factores que influyeron sobre la misma. Asimismo, se registró la mayor riqueza específica de ciliados en las bromelias del bosque mesófilo de montaña, donde a su vez fueron más frecuentes las especies de ciliados 'endémicos' (referidos como especies que sólo son exclusivas de bromelias) como *Glaucomides bromelicola*. Se presenta además un listado taxonómico que compila 170 especies de ciliados que han sido registradas en bromelias de diez países de la Región Neotropical. La mayoría son especies de las clases Oligohymenophorea, Colpodea y Spirotrichea. Los registros correspondieron a 52 especies de bromelias tanto epífitas como terrestres. México y Brasil contaron con el mayor número de especies. *Bromeliothrix metopoides* y *Glaucomides bromelicola* fueron las especies de ciliados con la mayor distribución a escala geográfica en las bromelias neotropicales. De éstas, algunas especies sólo han sido registradas en bromeliáceas de México, o bien, en algunas islas antillanas y otras únicamente se han observado en bromelias sudamericanas. Predominaron las especies libre nadadoras y junto con las formas sésiles, representaron aproximadamente el 2% del total de las especies conocidas para todo el phylum Ciliophora. De ellas, 16 se han catalogado como habitantes exclusivas de bromelias, pero sin mostrar alguna especificidad por determinada especie de bromelia. El resto de las especies de ciliados, en su mayoría son de distribución cosmopolita por ser frecuentes en ambientes como el suelo, musgos, espeletias y cuerpos de agua dulce, con una predominancia de especies bacterívoras.

ABSTRACT

Bromeliads with tank morphology enable the development of a phytotelm, which is considered a suitable habitat for the establishment of ciliate communities. The objective of this thesis was to record the species richness and to evaluate the influence of some environmental variables on the ciliate community that inhabit in epiphytic and terrestrial bromeliads from different types of forests in the Mexican Neotropics during the years 2014-2016, and to carry out a compilation of all the available ciliate species records from bromeliads, and their distribution along the Neotropical Region. To accomplish these objectives, a total of 189 plants were sampled. As a result of the present study, 48 ciliates species were recorded from 27 bromeliad species in five types of vegetation and some coffee lands from the states of Chiapas, Hidalgo, Jalisco, Oaxaca, Puebla, Veracruz and Yucatán, Mexico. More than 95% of the analyzed plants contained at least one ciliate species, and eight ciliate species were recorded for the first time in Mexico. The largest number of ciliates species was recorded in bromeliads from the dry tropical forest in the Resreve of the Biosphere Chamela Cuixmala, Jalisco, during the humid season of 2015 and 2016, specially in tank-less bromeliads or bromeliads with a poorly-developed phytotelm, like *Bromelia karatas* and *Tillandsia makoyana*, where free-living ciliate species were more common in relation to the sessile ones, which belonged to the sublass Peritrichia. Th especies *Drepanomonas revoluta*, *Glaucomides bromelicola*, *Leptopharynx bromeliophilus* and *Tetrahymena* sp. were the most frequent in the study. Some ecological aspects of the ciliate community were evaluated from different bromeliad species along an elevational gradient with fragments of pine forest, montane cloud forest, semideciduous tropical forest and coffee lands, located in Central Veracruz. Ciliate community composition was different depending of the type of forest, where altitude above sea level and water temperature in the bromeliads were identified as the three most important variables influencing the composition of the ciliate community. Species richness was larger in bromeliads from the montane cloud forest, where the so-called endemic ciliates (that inhabit only in bromeliads) like *Glaucomides bromelicola* were more frequent. A compilation of 170 ciliates species recorded in bromeliads from ten Neotropical countries is provided. Most of them are species that belong to the classes Oligohymenophorea, Colpodea and Spirotrichea. Species records were obtained from 52 species of epiphytic and terrestrial bromeliads. Mexico and Brazil showed the largest number of species records. *Bromeliothrix metopoides* and *Glaucomides bromelicola* were the two ciliate species with the widest geographic distribution inhabiting in Neotropical bromeliads. Some species have been recorded only in Mexican bromeliads, others were exclusive of bromeliads that inhabit in the Antillean islands, and others have only been observed from Southamerican bromeliads. Free-living species were more common in bromeliads, and by including sessiles ones, both represent almost the 2% of the total known species of the phylum Ciliophora. Sixteen species have been cataloged as exclsuive inhabitants of bromeliads, but there is no evidence of specificity between ciliates and certain bromeliad species. Most of the ciliates that inhabit in bromeliads have a cosmopolitan distribution, because they are conspicuous in soils, mosses, espeletias, and freshwater environments, and most of them are bacteria feeders.

INTRODUCCIÓN GENERAL

Los ciliados pertenecen al Phylum Ciliophora ubicado dentro del clado Alveolata debido a la presencia de alveolos debajo de la membrana, considerado un caracter sinapomórfico que comparten con otros protistas como los Apicomplexa, Colpodellida, Colponemida, Dinoflagellata y Perkinsidae (Adl *et al*., 2019). Citológicamente, los ciliados se caracterizan principalmente por la presencia de cilios derivados de cinetosomas con tres tipos de microfibrillas asociadas, un dualismo nuclear y la conjugación como proceso sexual. La ciliatura se dispone como somática y oral, en forma de monocinétidas, dicinétidas y policinétidas (Lynn, 1988, 2008).

Dentro del Phylum Ciliophora, se agrupan dos subphyla, once clases, 55 órdenes y aproximadamente 8,000 especies (Lynn, 2008). Del total de especies de ciliados a nivel mundial, alrededor de 4,500 son de vida libre, pero se ha estimado que un 80% de la diversidad de los ciliados permanece aún sin ser descrita (Foissner *et al*., 2007). En México, se han registrado 1,026 especies (Mayén-Estrada *et al*., 2019) lo que equivale casi al 12% de la diversidad del Phylum.

Los ciliados pueden ser solitarios o coloniales y presentan un tamaño entre 10-3,000 μm (Jones, 1974). Habitan como organismos de vida libre, ya sea libre nadadores o sésiles, formando parte del plancton de zonas neríticas y oceánicas y del bentos de ambientes marinos, cuerpos de agua dulce (lagos, ríos, cuerpos temporales y manantiales), lagos hipersalinos, ambientes salobres (lagunas costeras y manglares), plantas de tratamiento de aguas residuales, ambientes terrestres (suelos y musgos), semiterrestres o bien, como organismos simbiontes de invertebrados y vertebrados, con quienes incluso establecen hiperforesis (Sabagh *et al*., 2011), y en plantas acuáticas y cavidades de algunas plantas terrestres (Lynn, 2008, 2017) como las bromeliáceas.

Las Bromeliaceae son una familia diversa de angiospermas la cual agrupa cerca de 3,543 especies en 73 géneros cuya distribución es casi exclusiva del Neotrópico (Givnish *et al*., 2007, 2011; Gouda *et al.*, 2015), desde el sur de los Estados Unidos hasta Argentina y las Antillas (Frank *et al*., 2004; Givnish *et al*., 2011; Luther, 2006). Las bromeliáceas con morfología tanque captan el agua de lluvia entre las axilas de las hojas dando lugar a la formación de una fitotelma (Frank & Lounibos, 1987), que se define como un cuerpo de agua que se forma entre las inflorescencias, hojas o troncos de plantas y cuya acumulación es suficiente para que se establezcan comunidades de organismos acuáticos como los protistas ciliados (Maguire, 1971).

La diversidad de ciliados que habitan en bromelias de México es poco conocida. Durán-Ramírez *et al*. (2015) registraron 61 especies pertenecientes a ocho clases en dos especies de bromelias epífitas del género *Tillandsia*. Foissner (2010), Foissner & Stoeck (2011), Foissner *et al*. (2011) y Omar & Foissner (2011, 2012) documentaron y describieron algunas especies en *Tillandsia heterophylla* E. Morren del estado de Veracruz como *Bromeliothrix metopoides, Cotterillia bromelicola, Leptopharynx costatus costatus* y *L. bromeliophilus*.

Dunthorn *et al*. (2012) realizaron un análisis filogenético con especies de ciliados que habitan en las fitotelmata de bromelias, en donde se refieren secuencias genéticas de especies registradas en México. Foissner (2003a, b) y Foissner *et al*. (2003 y 2007) mencionaron que es probable que estas plantas alberguen a cientos de nuevas especies de ciliados implicando un proceso de evolución independiente vinculado a las limitaciones ecológicas propias de este microhábitat y paralelo al origen y diversificación de la familia Bromeliaceae en el Neotrópico.

En la actualidad, se conoce escasamente la influencia que ejercen los factores bióticos y abióticos sobre la composición de las comunidades de ciliados, así como su distribución dentro de diferentes especies de bromelias en distintos tipos de ecosistemas. Algunos estudios previos llevados a cabo en una población de *Aechmea distichanta* a lo largo del margen del Río Paraná, al sur de Brasil, han destacado la importancia del agua principalmente de origen pluvial para la presencia de ciliados en las bromelias, así como la influencia que representa la cercanía a cuerpos de agua dulce sobre la composición de la comunidad (Buosi *et al.*, 2014, 2015).

Se presentan los datos obtenidos de 48 especies de ciliados a partir de 27 especies de bromelias. El mayor número de especies se registró tanto en bromelias que no poseen morfología tanque como en algunas que poseen una fitotelma poco desarrollada en el bosque tropical caducifolio de la Reserva de la Biósfera Chamela Cuixmala en Jalisco durante la temporada húmeda de los años 2015 y 2016, de las cuales, la mayoría son ciliados cosmopolitas que habitan típicamente en suelos. A lo largo de un gradiente de elevación con fragmentos de distintos tipos de vegetación en el Centro de Veracruz, se identificó que el tipo de vegetación, la temperatura y la altitud sobre el nivel del mar, influyeron en la composición de las comunidades de ciliados. En bromelias del bosque mesófilo de montaña se observó una mayor riqueza específica, así como una mayor frecuencia de ciliados exclusivos de las bromelias. Estos resultados, junto con los registros previos disponibles en 52 especies de bromelias de diez países neotropicales, suman 170 especies que constituyen poco más del 2% de todas las especies conocidas para el phylum Ciliophora.

Capítulo I

Durán-Ramírez, C. A. & Mayén-Estrada, R. 2018.
Ciliate species from tank-less bromeliads in a dry tropical forest and their geographical distribution in the Neotropics.
Zootaxa 4497 (2): 241-257.

Artículo de requisito

Zootaxa 4497 (2): 241–257
http://www.mapress.com/j/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.4497.2.5
http://zoobank.org/urn:lsid:zoobank.org:pub:FDA9E213-7252-42C6-9251-2159CE804FF1

Ciliate species from tank-less bromeliads in a dry tropical forest and their geographical distribution in the Neotropics

CARLOS ALBERTO DURÁN-RAMÍREZ[1,2,3] & ROSAURA MAYÉN-ESTRADA[1]

[1]*Laboratorio de Protozoología, Departamento de Biología Comparada, Facultad de Ciencias, Universidad Nacional Autónoma de México, Circuito Ext. s/n, Ciudad Universitaria, Coyoacán, 04510 Ciudad de México, México*
[2]*Postgraduate Program in Biological Sciences, UNAM*
[3]*Corresponding author. E-mail: carlosduran_88@hotmail.com*

Abstract

The study of ciliate diversity in tropical environments remains scarce. In Neotropical forests, bromeliads are a common component of the vascular flora; bromeliads with tank morphology intercept rain water and detritus, resulting in the formation of a phytotelm, where heterotrophic protist communities like ciliates can establish. However, it is not known if ciliates inhabit tank-less bromeliads. For this reason, the goal of the present study was to investigate if ciliates can establish between the leaf axils of five terrestrial and epiphytic tank-less bromeliad species in a dry tropical forest in west Mexico. We collected samples of rain water and detritus from the leaf axils during the humid season of years 2015 and 2016. For ciliate taxonomical identification, we used optical microscopy, in vivo observation, and silver impregnation techniques. To summarize information about geographical distribution of ciliates identified at species level in the Neotropics, we provided their records from previous works, at country level with locality and georeferenciation. We recorded 27 taxa of ciliates, where the class Oligohymenophorea contained the largest richness of taxa. *Drepanomonas revoluta, Leptopharynx bromeliophilus*, and *Tetrahymena* sp. were recorded from all the species of bromeliads. *Bromelia karatas* was the species that hosted the largest number of ciliate taxa (22). Our results indicated that *Glaucomides bromelicola*, *Gonostomum bromelicola*, *Leptopharynx bromelicola* and *L. bromeliophilus*, species which are considered endemic to tank bromeliads, can also inhabit tank-less bromeliads. We provided previous records of 19 ciliate species from eleven countries within the Neotropical region, and *Bromeliothrix metopoides* was the species most frequently recorded in Neotropical countries (9). Therefore, tank-less bromeliads can constitute a temporal habitat for ciliates, and function as cysts reservoirs in environments with a pronounced seasonality like dry tropical forests.

Key words: cysts, endemic species, geographical distribution, phytotelm, species richness

Introduction

Neotropical dry forests are well known for their high biodiversity of plants and animals (Ceballos & García 1995); nevertheless, studies about ciliate diversity in tropical environments are scarce and fragmented at global scale. Some studies of terrestrial ciliates have been carried out in tropical forests of Africa (Dragesco & Dragesco Kernéis 1979, 1986). In the Neotropics, Foissner (1995, 1997, 2016) studied ciliate richness from floodplains and soils in the Amazon forest of Brazil, in Costa Rica, and from tropical terrestrial and semiterrestrial environments of Venezuela.

The family Bromeliaceae is an important component of the vascular flora of tropical forests, with ca. 3,543 species. Its distribution is almost restricted to Neotropics (Givnish *et al*. 2007, Gouda & Gouda 2015). Many species of the bromeliad subfamilies exhibit tank morphology (Givnish *et al*. 2014). Their coalescent leaves allow the accumulation of rain water and detritus, leading to the formation of a phytotelm (Maguire 1971), where heterotrophic protist such as ciliates can establish (Foissner *et al*. 2003, Durán-Ramírez *et al*. 2015). Other types of bromeliads are commonly terrestrial and miniaturized epiphytes, better known as nebulophytes or atmospheric forms, having various adaptations such as special hairs over the leaf to capture the mist from the air.

Accepted by L. Utz: 29 Aug. 2018; published: 9 Oct. 2018

The Reserve of the Biosphere Chamela-Cuixmala (RBCC), located in West Mexico, is the habitat of 28 bromeliad species, most found with epiphytic or terrestrial growth, some with tank morphology, tank-less and atmospehric forms (Espejo-Serna *et al*. 2004). Some bromeliad species, especially from the genus *Tillandsia*, are adapted to dry tropical forests where water is a limited resource due to a pronounced seasonality (Benzig 2000; Reyes-García *et al*. 2012; Trejo 2010).

Ciliates that inhabit bromeliads have only been recorded from species with tank morphology (Buosi *et al*. 2014, Dunthorn *et al*. 2012, Durán-Ramírez *et al*. 2015, Foissner *et al*. 2003), where water in the tanks is the most important factor for ciliate establishment (Buosi *et al*. 2014). Moreover, almost half of the species that can be found in tank bromeliads also inhabit soils of different regions of the world and show the ability to resist desiccation through the formation of cysts (Durán-Ramírez *et al*. 2015; Foissner 1998). However, it is not known if ciliates can establish in tank-less bromeliads that do not form a phytotelm.

The objective of this work was to investigate the richness of ciliates species that can inhabit in terrestrial and epiphytic tank-less bromeliads from the dry tropical forest of the RBCC. We also provided data of the previous records and habitats of the identified species in other localities of the Neotropics, in order to compilate the information from the literature about their geographical distribution of these species.

Methodology

Area of study. Two samplings were conducted during the humid season of years 2015 and 2016 (September and October respectively) at Estación de Biología Chamela-UNAM, located within the territory of the RBCC (19°37'–19°59'N 100°94'–105°06'W), municipality of La Huerta, along the coastal mountain range of Jalisco, West Mexico (fig. 1). The elevation ranges from 0 to 430 m asl and the humid season lasts four months, with an average annual precipitation of 750 mm (García-Oliva *et al*. 1995). The territory covers an area of ca. 32,000 acres and constitutes a portion of a fringe of dry tropical forests along the Mexican Pacific slope.

Sample collection. We collected 19 samples including water and detritus, or only detritus accumulated from the rosettes of five terrestrial and epiphytic tank-less bromeliad species of genera *Bromelia* L. 1753, and *Tillandsia* L. 1753. Epiphytic plants were located about 2.0 m above ground. All plants of year 2015 contained little volumes of rain water accumulated between their leaf axils. With the exception of one plant, bromeliads of year 2016 did not contain rain water. The samples were collected with new plastic pipettes and placed into sterilized Falcon tubes. For bromeliads that did not have water between their leaves, we only collected the detritus by using a fine spatula to carefully remove them over a tray. Both dry and water samples were maintained at room temperature. None of the plants were removed from their habitat. Taxonomical identity of bromeliads was investigated by photoidentification and according to Espejo-Serna & López-Ferrari (2005) and Espejo-Serna *et al*. (2004).

Ciliate identification. To carry out the taxonomical identification of ciliates, we analyzed each one of the water samples at least 48 hours after they were collected and at intervals of two days through the following two weeks. For dry samples, we rehydrated detritus with sterile distilled water one month after they were collected by using the non-flooded Petri dish technique (Foissner 1987a). Both types of samples were used to establish cultures in Petri dishes using drops of the original sample, table water Evian ®, and wheat infusion to stimulate bacterial growth (Foissner *et al.* 2003). We observed cytological characters of taxonomical importance *in vivo* (e.g. cell size and shape, position and shape of the cytostome, position and number of the contractile vacuoles) using bright field and differential interference contrast microscopy with a Nikon Labophot-2 microscope equipped with a Nikon Digital Sight DS-L15667 camera. We performed silver impregnation techniques according to the protocols of Foissner (2014), to reveal cytological characteristics. We followed Berger (1999), Certes (1891), Fernández-Galiano & Calvo (1992), Foissner (1987b, 1993, 2010, 2013, 2016), Foissner *et al.* (2011), Guggiari & Peck (2008), Lee *et al*. (2000), Omar & Foissner (2011, 2012a, b, 2014), Penard (1922), and Small (1967) for species identification. We followed the systematics according to Lynn (2008).

Geographical distribution. The circumscription of the Neotropical region in the American Continent was according to Morrone (2017). For geographical distribution and the habitats of ciliates identified at species level, we consulted previous published records from papers, theses as well as original descriptions of some taxa (Aladro-Lubel *et al.* 1990, 2006; Arévalo-Trear 1967; Bovee 1957; Buosi *et al*. 2014; Cruz-Jiménez 2017; Durán-Ramírez *et al*. 2015; Foissner 1995, 1997, 2000, 2010, 2013, 2016; Foissner *et al*. 2003; Foissner *et al*. 2011; Hardoim &

Heckman 1996; Hernández-Anaya 1981; Küppers & Claps 2012a,b, 2016; Madrazo-Garibay & López-Ochoterena 1982, 1985; Méndez-Sánchez 2017; Mondragón-Camarillo 2011; Omar & Foissner 2011; Pauleto *et al*. 2009; Rico-Ferrat 1990; Rondello-Bonatti *et al.* 2016; Sigala-Regalado 2011; Steffens & Wilbert 2002). Some species in Foissner (2013) and Foissner *et al.* (2003) with unique records where the sampling locality was not indicated, were included with a general georeferenciation at country level. Georeferences were obtained from original papers, or we did the georeferencing by using the program Google Earth Pro-2017, through the use of its search tool of localities and places in the map, and the name of the locality refered in the original work.

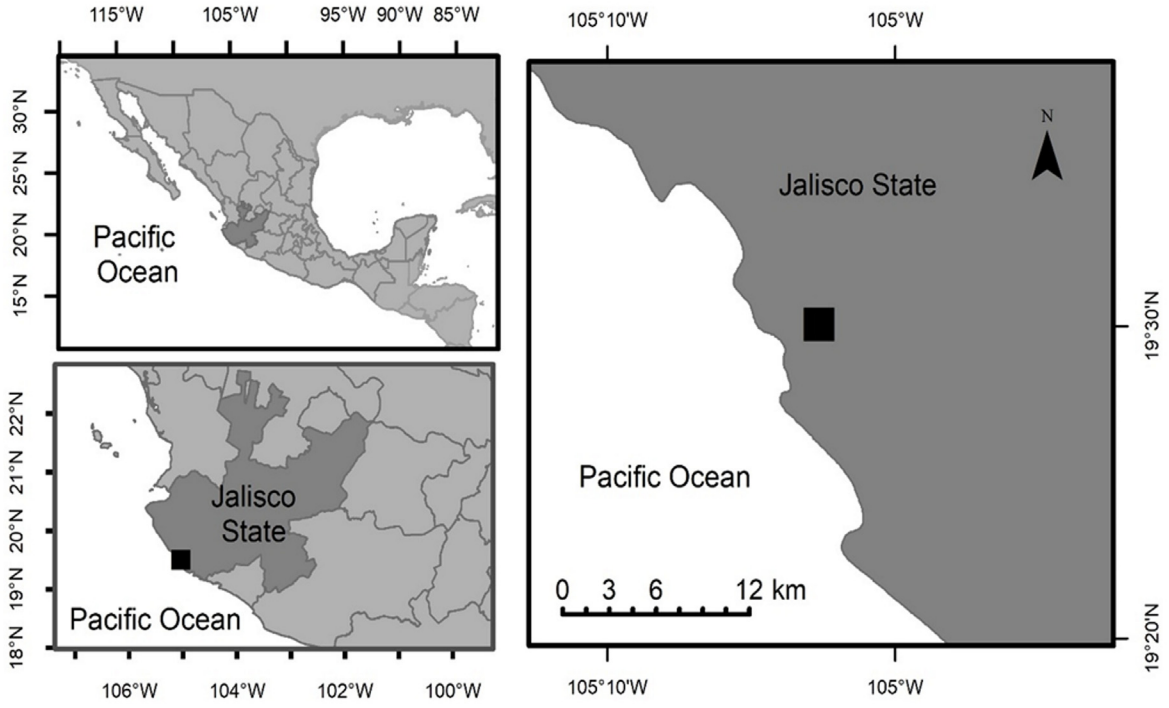


FIGURE 1. Location of the Biosphere Reserve Chamela-Cuixmala, Jalisco, Mexico.

Results

Ciliate species from tank-less bromeliads. From the bromeliad species *Bromelia karatas* L. 1753, *B. pinguin* L. 1753, *Tillandsia dasyliriifolia* Baker, 1887, *T. polystachia* (L. 1753) L. 1762 and *T. rothii* Rauh, 1976 (fig. 2), we recorded 27 taxa of ciliates, 19 of which were identified at species level. The taxa belonged to six classes as follows: Colpodea (seven taxa), Litostomatea (one taxa), Oligohymenophorea (eight taxa), Phyllopharyngea (one taxa), Nassophorea (six taxa), and Spirotrichea (four taxa) (table 1, fig. 3). From the field samples where little water was found between the leaves, we observed only four species as trophont stages (swimmers and active feeders): *Drepanomonas minuta*, *Epistyis* sp., and *Vorticella* sp. 1 and 2; from samples where detritus were rehydrated, we observed 13 species after their excystment: *Bresslauides terricola, Bromeliothrix metopoides, Glaucomides bromelicola, Gonostomum bromelicola*, *Lambornella* sp., *Leptopharynx brasiliensis*, *L. bromelicola*, *L. bromeliophilus*, *Odontochlamys gouraudi*, *Oxytricha* sp., *Parabryophrya* sp., *Pattersoniella vitiphila* and *Spathidium spatula*, and finally, ten species were recorded as both active or after their excystment (table 1): *Colpoda aspera*, *C. cucullus*, *C. maupasi*, *Cyclidium glaucoma*, *Drepanomonas revoluta*, *Frontonia* sp., *Leptopharynx costatus*, *Paracolpoda steinii*, *Phacodinium metchnikoffi* and *Tetrahymena* sp. We recorded the largest number of ciliate species from *Bromelia karatas* (22). *Drepanomonas revoluta, Leptopharynx bromeliophilus* and *Tetrahymena* sp. were recorded from all the bromeliad species.

Bresslauides terricola, Drepanomonas minuta, Leptopharynx brasiliensis, Phacodinium metchnikoffi, and *Spathidium spatula* were recorded inhabiting bromeliads for the first time worldwide. *Bresslauides terricola, D. minuta, Gonostomum bromelicola, L. brasiliensis, Pattersoniella vitiphila,* and *P. metchnikoffi* were recorded for the first time in Mexico (Aladro-Lubel *et al*. 2006) (fig. 3). *Bromeliothrix metopoides*, *Glaucomides bromelicola*, *Gonostomum bromelicola*, *Leptopharynx bromelicola*, and *L. bromeliophilus*, species considered as endemic or specific to tank bromeliads, were recorded for the first time in tank-less bromeliads.

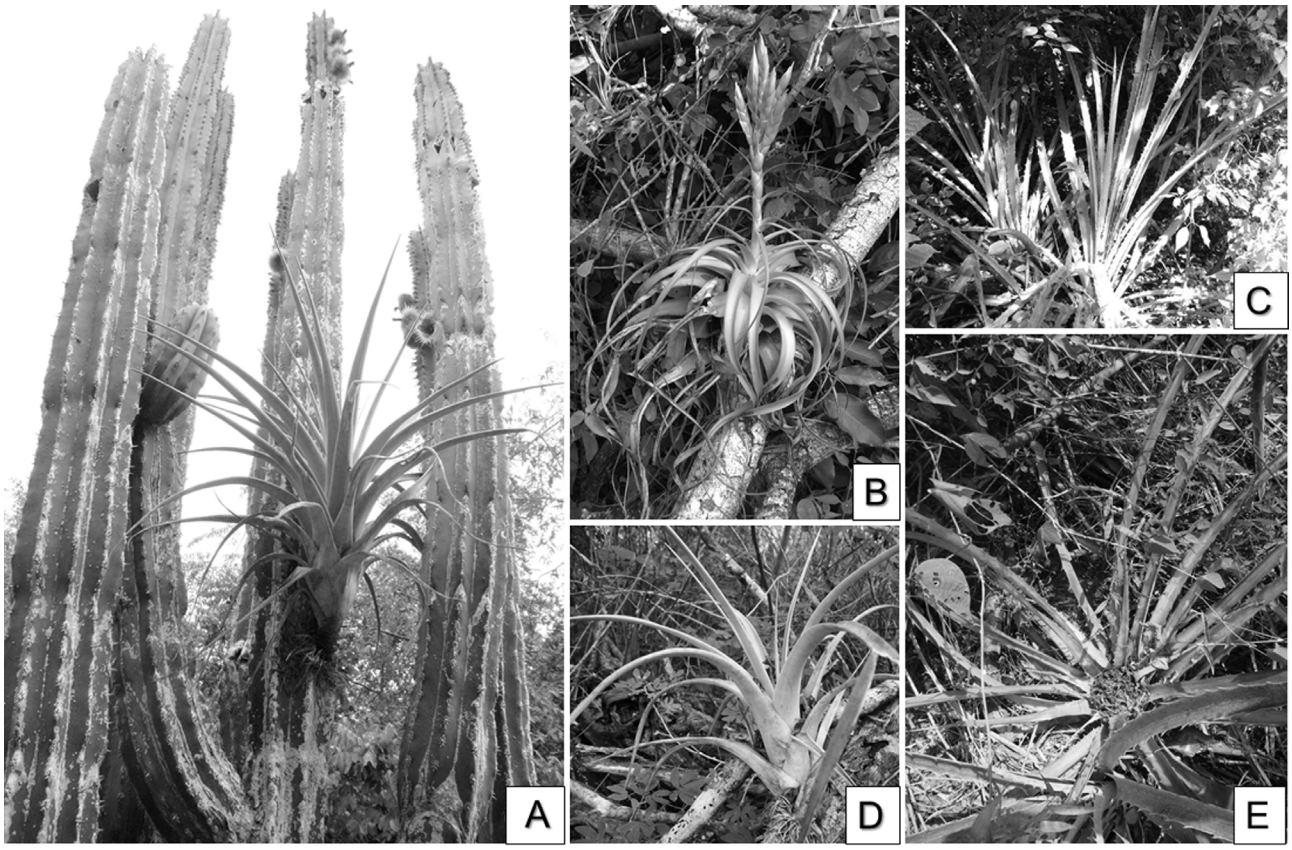


FIGURE 2. Bromeliad species sampled. A=*Tillandsia dasyliriifolia*, B=*T. rothii,* C=*Bromelia pinguin*, D=*T. polystachia* and E=*B. karatas*.

Geographical distribution

Bresslauides terricola (Foissner, 1987b) Foissner, 1993

Foissner, W. 1987b. *Zool. Beitr. N. F.* 31(2):187–282.

Habitat. Biological crusts, soil.

Distribution. **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49’49.79’’N 85º42’42.64’’W). **Venezuela**: Amazonas, near town of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W). Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W); Henri Pittier National Park (10°30’00.05’’N 67°37’33.64’’W). Falcón, Morrocoy National Park, near Chichiriviche (10°55’44.17’’N 69°19’44.72’’W).

References. Foissner 1995, 2016.

Bromeliothrix metopoides Foissner, 2010

Foissner, W. 2010. *Acta Protozool.* 49(3): 159–193.

Habitat. Moss, tank bromeliads.

TABLE 1. Ciliate species richness from tank-less bromeliads.

Ciliate species	s	Bk	Bp	Td	Tr	Tp	Class[3]
Bresslauides terricola[1, 2]	e	+	-	+	+	-	CO
*Bromeliothrix metopoides**	e	+	-	+	-	-	CO
Colpoda aspera	a,e	+	-	+	+	+	CO
Colpoda cucullus	a,e	+	-	+	+	+	CO
Colpoda maupasi	a,e	+	-	+	+	+	CO
Cyclidium glaucoma	a,e	+	-	+	+	+	OL
Drepanomonas minuta[1, 2]	a	+	-	+	-	+	NA
Drepanomonas revoluta	a,e	+	+	+	+	+	NA
Epistylis sp.	a	+	-	+	-	-	OL
Frontonia sp.	a,e	+	-	+	+	-	OL
*Glaucomides bromelicola**	e	-	-	-	+	-	OL
*Gonostomum bromelicola**[1]	e	+	-	+	+	-	SP
Lambornella sp.	e	+	-	-	+	-	OL
*Leptopharynx brasiliensis**[1, 2]	e	+	-	-	+	+	NA
*Leptopharynx bromelicola**	e	-	-	-	+	-	NA
*Leptopharynx bromeliophilus**	e	+	+	+	+	+	NA
Leptopharynx costatus	a,e	+	-	+	+	-	NA
Odontochlamys gouraudi	e	+	-	+	-	-	PH
Oxytricha sp.	e	-	-	-	+	-	SP
Parabryophrya sp.	e	+	-	-	+	-	CO
Paracolpoda steinii	a,e	+	-	+	+	+	CO
Pattersoniella vitiphila[1]	e	+	-	+	+	-	SP
Phacodinium metchnikoffi[1, 2]	a,e	+	+	-	+	+	SP
Spathidium spatula[2]	e	+	-	+	+	-	LI
Tetrahymena sp.	a,e	+	+	+	+	+	OL
Vorticella sp.1	a	-	-	+	-	-	OL
Vorticella sp.2	a	-	-	+	-	+	OL
Total of ciliate species		22	4	20	21	12	

Bromeliad species: Bk=*Bromelia karatas*, Bp=*Bromelia pinguin*, Td=*Tillandsia dasyliriifolia*, Tr=*Tillandsia rothii*, Tp=*Tillandsia polystachia.*

Ciliate classes: CO=Colpodea, LI=Litostomatea, NA=Nassophorea, OL=Oligohymenophorea, PH=Phyllopharyngea, SP=Spirotrichea.

s=trophic state of ciliate species at the moment of the sampling: a=active, e=encysted.

[1]=New record from Mexico.

[2]=New records of ciliates inhabiting in bromeliads.

[3]=Clasification system according to Lynn, 2008.

*Species with geographical distribution restricted to the Neotropics.

Distribution. **Brazil**: Paraiba, Nature Reserve Mata do Buraquinho, near the town of João Pessoa (7°08'13.74''S 34°51'31.35''W). Paraná, Nupélia Field Station near Porto São José (22°45'04.27''S 53°15'43.82''W); São Pedro do Paraná (22°43'16.90''S 53°10'10.85''W). **Costa Rica**: (9º54'N 84º05'W). **Chile**: (33º27' S 70º40'W). **Dominican Republic**: (18º28'N 69º56'W). **Ecuador**: (0º00' S 78º26'W). **Jamaica**: (18º01'N 76º48'W). **Mexico**: Oaxaca, near Ixtlán de Juárez (17°18'48.83''N 96°28'59.77''W); near Santiago Comaltepec (17°33'29.63''N 93°31'55.50''W). Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W). **Peru**: (11º59'N 77º03'S). **Venezuela**: (10º28'N 66º54'W).

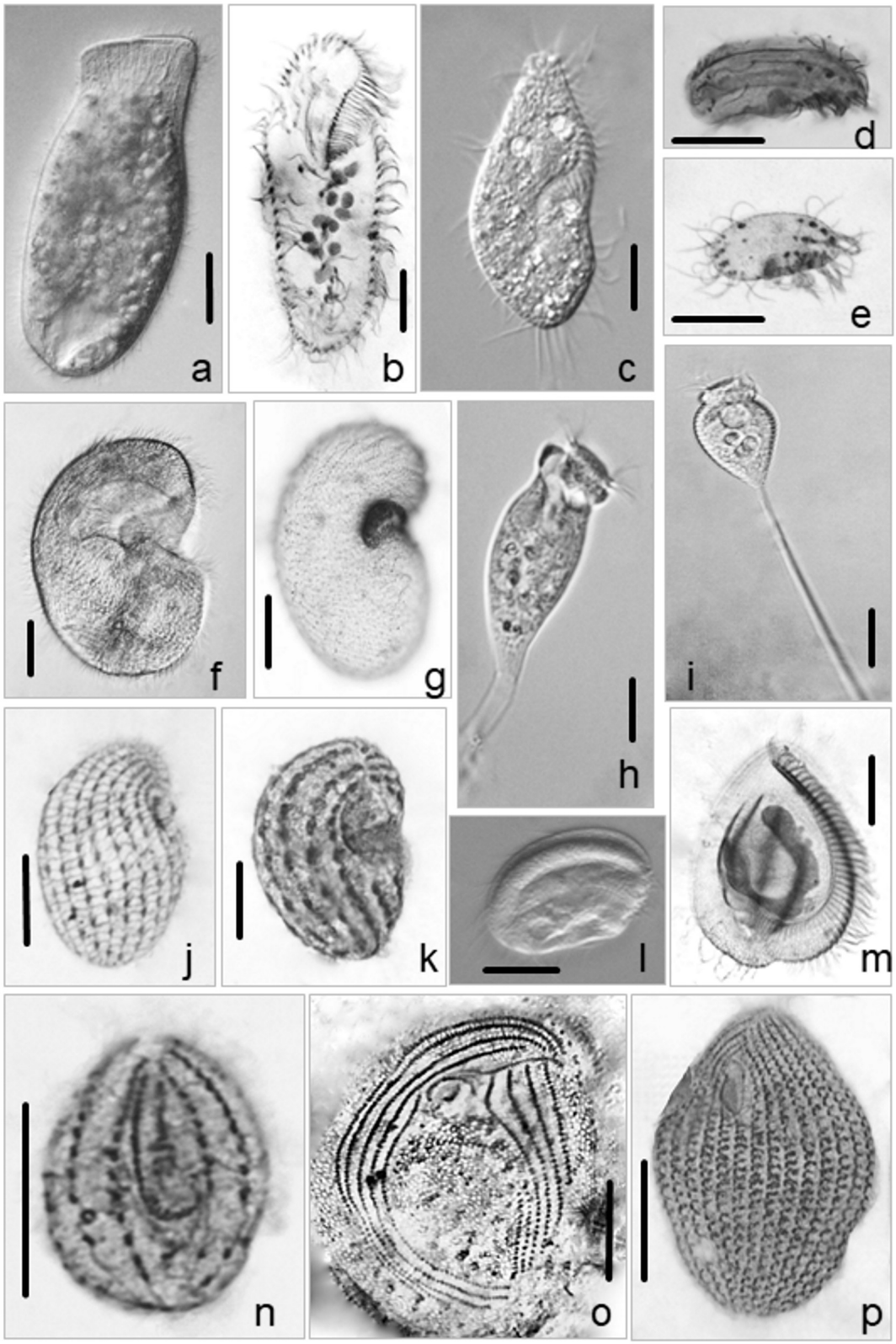


FIGURE 3. a–p. Ciliate from tank-less bromeliads in vivo (a, c, f, h, i, l), silver nitrate impregnation (e, j, k, n, o, p), protargol impregnation (b, d, m) and nigrosine (g). a. *Spathidium spathula*, b. *Pattersoniella vitiphila*, c. *Gonostomum bromelicola*, d. *Drepanomonas revoluta*, e. *D. minuta*, f. *Bresslauides terricola*, g. *Colpoda cucullus*, h. *Epistylis* sp., i. *Vorticella* sp., j. *C. maupasi*, k. *Colpoda aspera*, l. *Leptopharynx costatus*, m. *Phacodinium metchnikoffi*, n. *Cyclidium glaucoma*, o. *Odontochlamys gouraudi*, p. *Tetrahymena* sp. Scale bar: 10 µm. 20 X (f), 40 X (a, b, c, g, h, i, j, l, m, p), 100 X (d, e, k, n, o).

References: Buosi *et al*. 2014; Cruz-Jiménez 2017; Durán-Ramírez *et al*. 2015; Foissner 2010.

Colpoda aspera Kahl, 1926

Kahl, A. 1926. *Arch. Protistenk*. 55: 197–438.

Habitat. Flushs, lithotelmas, moss, swimming pools, tree litter, soil.

Distribution. **Brazil**: Amazonas, outskirts of Manaus (3°09'16.94''S 60°16'16.76''W). Bahia, inselbergs within the Atlantic rainforest zone (16°40'13.41''S 39°09'46.66''W). **Costa Rica**: Heredia, near Braulio Carrillo National Park (10°12'29.50''N 84°00'52.25''W); Puntarenas, near Monteverde Cloud Forest Reserve (10°18'28.07''N 84°47'48.29''W). **Ecuador**: Isabela Island at Sierra Negra Crater (0°57'00.59''S 90°57'31.25''W). **Mexico**: Morelos, swimming pool in Cuernavaca (18°55'45.14''N 99°13'58.58''W); on the road between Yecapixtla and Ocuituco (18°52'29.77''N 98°51'11.06''W). Oaxaca, near San Pablo Huitzo (17°15'34.10''N 96°52'24.42''W). **Venezuela**: Amazonas, Catanjapo River (5°41'33.29''N 67°36'18.70''W); 10 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); 14 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W). Apure, near Fundo El Tesoro (5°41'33.29''N 67°36'18.70''W); near El Sapo (5°41'33.29''N 67°36'18.70''W). Aragua, Henri Pittier National Park (10°30'00.05''N 67°37'33.64''W). Falcón, Golfete de Cuare (10°55'26.04''N 68°17'13.35''W); Morrocoy National Park (10°55'44.17''N 69°19'44.72''W); Pico de Chichiriviche (10°54'09.74''N 68°22'30.47''W). Guárico, near Cabruta (7°38'49.83''N 66°14'10.58''W). Mérida, outskirts of Mérida (8°36'52.64''N 71°09'30.67''W).

References: Arévalo-Trear 1967; Cruz-Jiménez 2017; Foissner 1997, 2016; Madrazo-Garibay & López-Ochoterena 1982; Steffens & Wilbert 2002.

Colpoda cucullus (Müller, 1773) Gmelin, 1790

Müller, O. F. 1773. Heineck & Faber, Havniae & Lipsiae: [l–30], 1–135.

Habitat. Biological crusts, decaying bark, *Espeletia* leaves, grasslands, guano, flushs, freshwater sponges, moss, ponds, rivers, soil, tank bromeliadas, tree litter.

Distribution. **Argentina**: Buenos Aires, 40 km south of La Plata City (35°23'22.85''S 57°48'08.79''W); Buenos Aires City (34°36'23.95''S 58°22'38.23''W). Córdoba (31°25'22.17''S 64°11'14.15''W). **Brazil**: Amazonas, vecinity of Manaus (3°09'16.94''S 60°16'16.76''W). Bahia, inselbergs within the Atlantic rainforest zone (16°40'13.41''S 39°09'46.66''W). Minas Gerais, inselbergs within the Atlantic rainforest zone (19°12'40.47''S 41°17'45.39''W). Paraná, Nupélia Field Station near Porto São José (22°45'04.27''S 53°15'43.82''W); São Pedro do Paraná (22°43'16.90''S 53°10' 10.85''W). **Colombia**: Leticia, near Leticia town (4°09'51.10''S 69°58'18.04''W). **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49'49.79''N 85º42'42.64''W). Puntarenas, Monteverde Cloud Forest Reserve (10°18'28.07''N 84°47'48.29''W). **Ecuador**: Isabela Island (0°57'00.59''S 90°57'31.25''W). San Cristóbal Island (0°48'11.41''S 89°25'59.56''W). Santa Cruz Island (0°44'20.16''S 90°18'37.73''W). **Peru**: Loreto, vecinity of Iquitos (3°46'50.45''S 74°21'05.75''W). **Mexico**: Guerrero, La Joya cave (18°35'13.95''N 99°33'56.76''W). Morelos, on the road between Yecapixtla and Ocuituco (18°52'29.77''N 98°51'11.06''W). Tabasco, grassland near Cunduacán (18°02'42.19''N 93°09'22,72''W). Tamaulipas, near Gómez Farías, Rancho El Cielo (22°51'10.80''N 99°07'19.35''W). Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); Jalacingo, Ejido Orilla del Monte (19°48'06.88''N 97°18'16.44''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); 14 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); Catanjapo River (5°41'33.29''N 67°36'18.70''W); near Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); near Orinoco River (5°41'33.29''N 67°36'18.70''W); Pavoni (5°41'33.29''N 67°36'18.70''W). Apure, near Fundo El Tesoro (5°41'33.29''N 67°36'18.70''W); near El Sapo (5°41'33.29''N 67°36'18.70''W). Aragua, Biological Station Rancho Grande (10°23'20.36''N 67°37'07.85''W); Henri Pitter National Park (10°30'00.05''N 67°37'33.64''W); near Ocumare (10°30'00.05''N 67°37'33.64''W). Bolívar, 100 km southwest to Cabruta (7°00'29.36''N 66°05'48.69''W); outskirts of Village of Raimundo (7°03'33.83''N 66°55'39.03''W). Falcón, Golfete de Cuare (10°55'26.04''N 68°17'13.35''W); Morrocoy National Park (10°55'44.17''N 69°19'44.72''W); Pico de Chichiriviche (10°54'09.74''N 68°22'30.47''W); surroundings of the village of Chichiriviche (10°54'09.74''N 68°22'30.47''W). Guárico, near

Cabruta (7°38’49.83’’N 66°14’10.58’’W). Mérida, Cordillera de Mérida (8°52’38.68’’N 70°48’41.56’’W); outskirts of Mérida (8°36’52.64’’N 71°09’30.67’’W); Páramo de Piedras Blancas, near Pico del Águila (8°52’24.71’’N 70°48’31.65’’W).

References: Aladro-Lubel *et al*. 2006; Arévalo-Trear 1967; Bovee 1957; Buosi *et al*. 2014; Durán-Ramírez *et al*. 2015; Foissner 1995, 1997, 2000, 2016; Foissner *et al*. 2003; Küppers & Claps 2012b; Mondragón-Camarillo 2011; Rico-Ferrat 1990; Sigala-Regalado 2011; Steffens & Wilbert 2002.

Colpoda maupasi Enriques, 1908

Enriques, P. 1908. *Arch. Zool. Exp. Gén*. 8: 1–15.

Habitat. Biological crusts, coastal lagoons, decaying bark, guano, mangrove, moss, rivers, soil, tank bromeliads, tree litter.

Distribution. **Brazil:** Amazonas: Janauari Region, 20 km east of Manaus (3°12’53.11’’S 60°02’46.31’’W); Rio Negro, Anavilhanas archipielago (2°38’09.53’’S 60°55’33.53’’W); vecinity of Manaus (3°09’16.94’’S 60°16’16.76’’W). Bahia, inselbergs within the Atlantic rainforest zone (16°40’13.41’’S 39°09’46.66’’W). Minas Gerais, inselbergs within the Atlantic rainforest zone (19°12’40.47’’S 41°17’45.39’’W). **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49’49.79’’N 85º42’42.64’’W). Heredia, near Braulio Carrillo National Park (10°12’29.50’’N 84°00’52.25’’W). Puntarenas, Monteverde Cloud Forest Reserve (10°18’28.07’’N 84°47’48.29’’W). **Dominican Republic**: (18º28’N 69º56’W). **Ecuador**: Isabela Island, surroundings of the village of Puerto Villamil (0°57’00.59’’S 90°57’31.25’’W); Sierra Negra Crater (0°57’S 90°57’W). San Cristóbal Island (0°48’11.41’’S 89°25’59.56’’W). Santa Cruz Island (0°44’20.16’’S 90°18’37.73’’W). **Mexico**: Guerrero, La Joya cave (18°35’13.95’’N 99°33’56.76’’W). Michoacán, Tziranda cave (19°38’23.93’’N 100°30’06.94’’W); Huarimio cave (18°39’44.69’’N 100°53’08.35’’W). Morelos, on the road betweem Yecapixtla and Ocuituco (18°52’29.77’’N 98°51’11.06’’W). Nayarit, San Blas (21°31’42.67’’N 105°16’49.34’’W). Veracruz, in coffee lands near Coatepec (19°25’02.46’’N 96°58’28.02’’W); Ixtaczoquitlán, Galicia cave (18°47’04.82’’N 96°59’11.05’’W); Veracruz, temporary lake (19°12’59.52’’N 96°09’56.66’’W); near Xalapa, Santuario del Bosque de Niebla (19°30’56.50’’N 96°56’41.65’’W). **Peru**: Loreto, vecinity of Iquitos (3°46’50.45’’S 74°21’05.75’’W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W); 14 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W); 50 km north of Puerto Ayacucho (6º06’29.45’’S 67º30’07.53’’W); Catanjapo River (5°41’33.29’’N 67°36’18.70’’W). Apure, near El Sapo (5°41’33.29’’N 67°36’18.70’’W). Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W); Henri Pittier National Park (10°30’00.05’’N 67°37’33.64’’W). Bolívar, 100 km southwest to Cabruta (7°00’N 66°05’W); outskirts of Village of Raimundo (7°03’33.83’’N 66°55’39.03’’W). Falcón, Golfete de Cuare (10°55’26.04’’N 68°17’13.35’’W); Morrocoy National Park, near Chichiriviche (10°55’44.17’’N 69°19’44.72’’W); surroundings of the village of Chichiriviche (10°54’09.74’’N 68°22’30.47’’W). Guárico, near Cabruta (7°38’49.83’’N 66°14’10.58’’W). Mérida, outskirts of Mérida (8°36’52.64’’N 71°09’30.67’’W).

References: Aladro-Lubel *et al*. 1990; Arévalo-Trear 1967; Durán-Ramírez *et al*. 2015; Foissner 1995, 1997, 2016; Foissner *et al.* 2003; Hernández-Anaya 1981; Sigala-Regalado 2011; Steffens & Wilbert 2002.

Cyclidium glaucoma Müller, 1773

Müller, O. F. 1773. Heineck & Faber, Havniae & Lipsiae: [I–30], 1–135.

Habitat. Coastal lagoons, detritus, lakes, marine, sediments, submerged plants, rivers, soil, tank bromeliads, tree litter.

Ditribution. **Argentina**: Buenos Aires, 40 km south of La Plata City (35°23’22.85’’S 57°48’08.79’’W); Poblet (35°04’27.09’’S 57°57’54.05’’W). **Brazil**: Mato Grosso, northern part of the Pantanal (15°36’54.16’’S 56°56’12.85’’W). Paraná, Nupélia Field Station near Porto São José (22°45’04.27’’S 53°15’43.82’’W); São Pedro do Paraná (22°43’16.90’’S 53°10’ 10.85’’W); upper Paraná river floodplain (22°42’06.63’’S 53°06’09.26’’ W). São Paulo**,** Atibaia river (23°10’27.07’’S 46°39’31.27’’W). **Costa Rica**: Heredia, near Braulio Carrillo National

Park (10°12’29.50’’N 84°00’52.25’’W). **Mexico**: Campeche, Términos lagoon (18°38’19.22’’N 91°45’52.59’’W); Pom lagoon (18°34’21.23’’N 92°08’43.52’’W). Chiapas, Lake Tziscao (16°04’43.22’’N 91°40’39.55’’W). Guerrero, La Joya cave (18°35’13.95’’N 99°33’56.76’’W). Michoacán, Tziranda cave (19°38’23.93’’N 100°30’06.94’’W). Morelos, Cuernavaca, Salto San Antón (18°55’31.22’’N 99°14’34.49’’W). Nayarit, San Blas (21°31’42.67’’N 105°16’49.34’’W). Oaxaca, Lake Analco (17°24’12.36’’N 96°31’45.41’’W); Presa La Azucena (17°05’20.49’’N 96°39’24.58’’W). Tamaulipas, Gómez Farías, Rancho El Cielo (22°51’10.80’’N 99°07’19.35’’W). Veracruz, Boca del Rio (19°05’37.58’’N 96°05’54.99’’W); Alvarado, Mandinga lagoon (19°00’44.95’’N 96°05’49.53’’W); coffee lands near Coatepec (19°25’02.46’’N 96°58’28.02’’W); Jalacingo, Ejido Orilla del Monte (19°48’06.88’’N 97°18’16.44’’W); Veracruz, temporary lake (19°13’06.02’’N 96°11’33.34’’W); near Xalapa, Santuario del Bosque de Niebla (19°30’56.50’’N 96°56’41.65’’W). **Venezuela**: Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W).

References: Aladro-Lubel *et al*. 1990, 2006; Buosi *et al*. 2014; Durán-Ramírez *et al*. 2015; Foissner 1997, 2016; Hardoim & Heckman 1996; Hernández-Anaya 1981; Küppers & Claps 2012b; Madrazo-Garibay & López-Ochoterena 1985; Méndez-Sánchez 2017; Mondragón-Camarillo 2011; Pauleto *et al*. 2009; Rico-Ferrat 1990; Rondello-Bonatti *et al.* 2016; Sigala-Regalado 2011.

Drepanomonas minuta Foissner & Omar, 2014

Omar, A. & Foissner, W. 2014. *Acta Protozool.* 53:295–311.

Habitat. Soil

Distribution. **Ecuador**: Santa Cruz Island (0°44’20.16’’S 90°18’37.73’’W). **Venezuela**: Amazonas, 14 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W).

References. Foissner 2016.

Drepanomonas revoluta Penard, 1922

Penard, E, 1922. Georg & Cie, Éditeurs. Géneve. 1–331.

Habitat. Biological crusts, decaying bark, flushs, guano, moss, rivers, soil, tank bromeliads, tree litter.

Distribution. **Brazil**: Bahia, inselbergs within the Atlantic rainforest zone (16°40’13.41’’S 39°09’46.66’’W). Mato Grosso, northern part of the Pantanal (15°36’54.16’’S 56°56’12.85’’W). Minas Gerais, inselbergs within the Atlantic rainforest zone (19°12’40.47’’S 41°17’45.39’’W). Paraná, Nupélia Field Station near Porto São José (22°45’04.27’’S 53°15’43.82’’W); São Pedro do Paraná (22°43’16.90’’S 53°10’ 10.85’’W). Rio de Janeiro, inselbergs within the Atlantic rainforest zone (22°29’25.68’’S 42°52’56.35’’W). **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49’49.79’’N 85º42’42.64’’W). **Dominican Republic**: (18º28’N 69º56’W). **Mexico**: Guerrero, La Joya cave (18°35’13.95’’N 99°33’56.76’’W). Oaxaca, near Ixtlán de Juárez (17°18’48.83’’N 96°28’59.77’’W); near San Pablo Huitzo (17°15’34.10’’N 96°52’24.42’’W). Veracruz, Ixtaczoquitlán, Galicia cave (18°47’04.82’’N 96°59’11.05’’W); coffee lands near Coatepec (19°25’02.46’’N 96°58’28.02’’W); near Xalapa, Santuario del Bosque de Niebla (19°30’56.50’’N 96°56’41.65’’W). **Peru**: Loreto, vecinity of Iquitos (3°46’50.45’’S 74°21’05.75’’W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W); 14 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W). Apure, near Fundo El Tesoro (5°41’33.29’’N 67°36’18.70’’W); near El Sapo (5°41’33.29’’N 67°36’18.70’’W). Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W); Henri Pittier National Park (10°30’00.05’’N 67°37’33.64’’W); near Ocumare (10°30’00.05’’N 67°37’33.64’’W). Bolívar, 100 km southwest to Cabruta (7°00’29.36’’N 66°05’48.69’’W). Falcón, about 13 km northwest of the village of Chichiriviche (11°00’07.16’’N 68°23’12.09’’W); Morrocoy National Park, Pico de Chichiriviche (10°55’44.17’’N 69°19’44.72’’W). Guárico, near Cabruta (7°38’49.83’’N 66°14’10.58’’W).

References. Buosi *et al*. 2014; Cruz-Jiménez 2017; Durán-Ramírez *et al*. 2015; Foissner 1995, 1997, 2016; Foissner *et al*. 2003; Rondello-Bonatti *et al*. 2016; Sigala-Regalado 2011; Steffens & Wilbert 2002.

***Glaucomides bromelicola* Foissner, 2013**

Foissner, W. 2013. *J. Eukaryot. Microbiol.* 60: 137–157.

Habitat. Tank bromeliads.

Distribution. **Chile**: (33º27' S 70º40'W). **Dominican Republic**: Puerto Plata, Botanical Garden (19°48'29.03''N 70°42'42.23''W). **Ecuador**: (0º00' S 78º26'W). **Jamaica**: (18º01'N 76º48'W). **Mexico**: Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W). **Peru**: (11º59'N 77º03'S). **Venezuela**: (10º28'N 66º54'W).

References. Durán-Ramírez *et al*. 2015; Foissner 2013.

***Gonostomum bromelicola* Foissner, 2016**

Foissner, W. 2016. *Denisia* 35: 1–912.

Habitat. Tank bromeliads.

Distribution. **Jamaica**, Trelawny (18°15'46.98''N 77°41'59.03''W).

References. Foissner 2016

***Leptopharynx brasiliensis* Foissner & Omar, 2012b**

Omar, A. & Foissner, W. 2012. *Eur. J. Protistol*. 48: 30–47.

Habitat. Soil, tree litter.

Distribution. **Brazil**: Mato Grosso, near Poconé (16º39'28.35''S 56º45'34.55''W). **Venezuela**: Amazonas, 50 km north of Puerto Ayacucho (6º06'29.45''S 67º30'07.53''W); near El Sapo (5°41'33.29''N 67°36'18.70''W).

References. Foissner 2016; Omar & Foissner 2012b.

***Leptopharynx bromelicola* Foissner *et al*., 2011**

Foissner, Wolf, Yashchenko & Stoeck, 2011. *J. Eukaryot. Microbiol*. 58(2):134–151.

Habitat. Tank bromeliads.

Distribution. **Jamaica**: Slope of the Blue Mountains, Jamaica, Silver Hill village (18°12'01.48''N 76°40'44.46''W). **Mexico**: Oaxaca, near Ixtlán de Juárez (17°18'48.83''N 96°28'59.77''W). Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W).

References. Durán-Ramírez *et al*. 2015; Foissner *et al*. 2011.

***Leptopharynx bromeliophilus* Omar & Foissner, 2011**

Omar & Foissner, 2011. *Acta Protozool*. 50:89–103.

Habitat. Tank bromeliads.

Distribution. **Jamaica**: Ecclesdown (18°03'45.09''N 76°20'25.62''W). **Mexico**: Oaxaca, near Ixtlán de Juárez (17°18'48.83''N 96°28'59.77''W). Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W).

References. Durán-Ramírez *et al*. 2015; Omar & Foissner 2011.

Leptopharynx costatus Mermod, 1914

Mermod, G. 1914. *Revue Suisse Zool*. 22: 31–114.

Habitat. Biological crusts, decaying bark, *Espeletia* leaves, freshwater sponges, guano, moss, soil, tank bromeliads, tree litter.

Distribution. **Brazil**: Amazonas, Janauari Region, 20 km east of Manaus (3°12'53.11''S 60°02'46.31''W); outskirts of Manaus (3°09'16.94''S 60°16'16.76''W); Rio Negro, Anavilhanas archipielago (2°38'09.53''S 60°55'33.53''W). Paraná, Nupélia Field Station near Porto São José (22°45'04.27''S 53°15'43.82''W); São Pedro do Paraná (22°43'16.90''S 53°10' 10.85''W). **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49'49.79''N 85º42'42.64''W). Heredia, Braulio Carrillo National Park (10°12'29.50''N 84°00'52.25''W). Puntarenas, near Monteverde Cloud Forest Reserve (10°18'28.07''N 84°47'48.29''W). **Dominican Republic**: (18º28'N 69º56'W). **Ecuador**: (0º00' S 78º26'W). **Mexico**: Guerrero: La Joya cave (18°35'13.95''N 99°33'56.76''W). Oaxaca, near Ixtlán de Juárez (17°18'48.83''N 96°28'59.77''W). Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W); near Xalapa, Santuario del Bosque de Niebla (19°30'56.50''N 96°56'41.65''W). **Peru**: Loreto, vecinity of Iquitos (3°46'50.45''S 74°21'05.75''W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); 14 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); 50 km north of Puerto Ayacucho (6º06'29.45''S 67º30'07.53''W); Pavoni (5°41'33.29''N 67°36'18.70''W). Apure, near El Sapo (5°41'33.29''N 67°36'18.70''W); near Fundo El Tesoro (5°41'33.29''N 67°36'18.70''W). Aragua, Biological Station Rancho Grande (10°23'20.36''N 67°37'07.85''W); Henri Pittier National Park (10°30'00.05''N 67°37'33.64''W); near Ocumare (10°30'00.05''N 67°37'33.64''W). Bolívar, 100 km southwest to Cabruta (7°00'29.36''N 66°05'48.69''W); outskirts of Village of Raimundo (7°03'33.83''N 66°55'39.03''W). Falcón, Morrocoy National Park, near Chichiriviche (10°55'44.17''N 69°19'44.72''W). Guárico, near Cabruta (7°38'49.83''N 66°14'10.58''W). Mérida, Páramo de Piedras Blancas, near Pico del Águila (8°52'24.71''N 70°48'31.65''W).

References. Buosi *et al*. 2014; Durán-Ramírez *et al*. 2015; Foissner 1995, 1997, 2000, 2016; Foissner *et al*. 2003; Sigala-Regalado 2011.

Odontochlamys gouraudi Certes, 1891

Certes, A. 1891. *Mém. Soc. Zool. Fr.* 4: 536–541.

Habitat. Soil, tank bromeliads.

Distribution. **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49'49.79''N 85º42'42.64''W). **Mexico**: Veracruz, in coffee lands near Coatepec (19°25'02.46''N 96°58'28.02''W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W); 50 km north of Puerto Ayacucho (6º06'29.45''S 67º30'07.53''W). Apure, near Fundo El Tesoro (5°41'33.29''N 67°36'18.70''W).

References. Durán-Ramírez *et al*. 2015; Foissner 1995, 2016.

Paracolpoda steinii (Maupas, 1883)

Maupas, É. 1883. *Archs Zool. Exp. Gen*. (Ser. 2) 11: 427–664.

Habitat. Biological crusts, coastal lagoons, decaying bark, *Espeletia* leaves, flushs, grasslands, lithotelmas, moss, rivers, soil, tank bromeliads, temporary lake, tree litter.

Distribution. **Argentina**: Buenos Aires City (34°36'23.95''S 58°22'38.23''W); Poblet (35°04'27.09''S 57°57'54.05''W). Córdoba (31°25'22.17''S 64°11'14.15''W). **Brazil**: Amazonas, outskirts of Manaus (3°09'16.94''S 60°16'16.76''W); Rio Negro, Anavilhanas archipielago (2°38'09.53''S 60°55'33.53''W). Bahia, inselbergs within the Atlantic rainforest zone (16°40'13.41''S 39°09'46.66''W). Minas Gerais, inselbergs within the Atlantic rainforest zone (19°12'40.47''S 41°17'45.39''W). Rio de Janeiro, inselbergs within the Atlantic rainforest zone (22°29'25.68''S 42°52'56.35''W). Paraná, Nupélia Field Station near Porto São José

(22°45’04.27’’S 53°15’43.82’’W); São Pedro do Paraná (22°43’16.90’’S 53°10’ 10.85’’W); upper Paraná river floodplain (22°42’06.63’’S 53°06’09.26’’ W). São Paulo, inselbergs within the Atlantic rainforest zone (23°11’08.32’’S 45°01’27.49’’ W). **Costa Rica**: Heredia, near Braulio Carrillo National Park (10°12’29.50’’N 84°00’52.25’’W); Puntarenas, near Monteverde Cloud Forest Reserve (10°18’28.07’’N 84°47’48.29’’W). **Dominican Republic**: (18º28’N 69º56’W). **Ecuador**: (0º00’ S 78º26’W)**.** Isabela Island at Sierra Negra Crater (0°57’00.59’’S 90°57’31.25’’W). Isabela Island, surroundings of the village of Puerto Villamil (0°57’00.59’’S 90°57’31.25’’W). San Cristóbal Island (0°48’11.41’’S 89°25’59.56’’W). Santa Cruz Island (0°44’20.16’’S 90°18’37.73’’W). **Mexico**: Nayarit, San Blas (21°31’42.67’’N 105°16’49.34’’W). Tamaulipas, Gómez Farías, Rancho El Cielo (22°51’10.80’’N 99°07’19.35’’W). Veracruz, in coffee lands near Coatepec (19°25’02.46’’N 96°58’28.02’’W); Jalacingo, Ejido Orilla del Monte (19°48’06.88’’N 97°18’16.44’’W); Veracruz, temporary lake (19°13’06.02’’N 96°11’33.34’’W); near Xalapa, Santuario del Bosque de Niebla (19°30’56.50’’N 96°56’41.65’’W). **Peru**: Loreto, vecinity of Iquitos (3°46’50.45’’S 74°21’05.75’’W). **Venezuela**: Amazonas: 10 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W); 14 km north of Puerto Ayacucho (5°41’33.29’’N 67°36’18.70’’W); Pavoni (5°41’33.29’’N 67°36’18.70’’W). Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W); Henri Pittier National Park (10°30’00.05’’N 67°37’33.64’’W). Apure: near El Sapo (5°41’33.29’’N 67°36’18.70’’W). Bolívar, 100 km southwest to Cabruta (7°00’29.36’’N 66°05’48.69’’W); outskirts of Village of Raimundo (7°03’33.83’’N 66°55’39.03’’W). Falcón, about 13 km northwest of the village of Chichiriviche (11°00’07.16’’N 68°23’12.09’’W); Golfete de Cuare (10°55’26.04’’N 68°17’13.35’’W); Morrocoy National Park, near Chichiriviche (10°55’44.17’’N 69°19’44.72’’W); Pico de Chichiriviche (10°54’09.74’’N 68°22’30.47’’W). Guárico, near Cabruta (7°38’49.83’’N 66°14’10.58’’W). Mérida, outskirts of Mérida (8°36’52.64’’N 71°09’30.67’’W); Páramo de Piedras Blancas, near Pico del Águila (8°52’24.71’’N 70°48’31.65’’W); Sierra Nevada National Park, surroundings of La Mucuy (8°37’’55.79’’N 71°02’12.20’’W).

References. Aladro-Lubel *et al*. 1990; Buosi *et al*. 2014; Foissner 1997, 2000, 2016; Foissner *et al*. 2003; Durán-Ramírez *et al*. 2015; Hernández-Anaya 1981; Küppers & Claps 2012a, 2016; Mondragón-Camarillo 2011; Pauleto *et al.* 2009; Rico-Ferrat 1990; Steffens & Wilbert 2002.

Pattersoniella vitiphila Foissner, 1987b

Foissner, W. 1987b. *Zool. Beitr. N. F.* 31(2):187–282.

Habitat. Alluvial soil, soil, tank bromeliads.

Distribution. **Brazil**: Paraná, Nupélia Field Station near Porto São José (22°45’04.27’’S 53°15’43.82’’W); São Pedro do Paraná (22°43’16.90’’S 53°10’ 10.85’’W). **Dominican Republic**: (18º28’N 69º56’W). **Venezuela**: Aragua, Henri Pittier National Park (10°30’00.05’’N 67°37’33.64’’W).

References. Buosi *et al*. 2014; Foissner 2016; Foissner *et al*. 2003.

Phacodinium metchnikoffi (Certes, 1891) Prowazek, 1900

Certes, A. 1891. *Mém. Soc. Zool. Fr.* 4: 536–541.

Habitat. Moss, soil.

Distribution. **Brazil**: Rio Negro, Anavilhanas archipielago (2°38’09.53’’S 60°55’33.53’’W). **Mexico**: Oaxaca, near San Pablo Huitzo (17°15’34.10’’N 96°52’24.42’’W). **Venezuela**: Apure, near El Sapo (5°41’33.29’’N 67°36’18.70’’W). Aragua, Biological Station Rancho Grande (10°23’20.36’’N 67°37’07.85’’W); near Ocumare (10°30’00.05’’N 67°37’33.64’’W). Guárico, near Cabruta (7°38’49.83’’N 66°14’10.58’’W).

References. Cruz-Jiménez 2017; Foissner 1997, 2016.

Spathidium spathula (Müller, 1773) Bütschli, 1889

Müller, O. F. 1773. Heineck & Faber, Havniae & Lipsiae: [I–30], 1–135.

Habitat. Pools, soil.

Distribution. **Argentina**: Buenos Aires City (34°36'23.95''S 58°22'38.23''W). **Brazil**: Amazonas, outskirts of Manaus (3°09'16.94''S 60°16'16.76''W). **Costa Rica**: Guanacaste, Santa Rosa National Park (10º49'49.79''N 85º42'42.64''W). **Venezuela**: Amazonas, 10 km north of Puerto Ayacucho (5°41'33.29''N 67°36'18.70''W). Apure, near El Sapo (5°41'33.29''N 67°36'18.70''W). Aragua, Biological Station Rancho Grande (10°23'20.36''N 67°37'07.85''W).

References. Foissner 1995, 1997, 2016; Küppers & Claps 2012a.

Discussion

Previous studies about ciliate communities from bromeliads have been carried out only from species with tank morphology. Our results provide evidence that other species, and even other genera of tropical tank-less bromeliads, with a similar vegetative architecture to *Espeletia* from the Andean paramos (Foissner 2000), constitute a habitat for ciliates. Ciliate species richness recorded from a tank-less bromeliad species like *T. dasyliriifolia* was lower in comparison with tank bromeliads like the *Tillandsia biflora* complex from a montane cloud forest in Central Mexico (Durán-Ramírez *et al*. 2015), or *Aechmea distichantha* from a tropical subdecidous forest in South Brazil (Buosi *et al*. 2014), which contained double and triple species richness respectively. In addition to the bromeliad morphology, the type of forest might be influencing the ciliate species composition in bromeliads. In the case of terrestrial bromeliads like *B. karatas* and *B. pinguin*, their proximity to the ground can be an important factor that allows colonization of soil ciliates like colpodids and spirotricheans, which were the most common ciliates in our samples.

The dry season in the RBCC lasts two thirds of the year. For this reason, terrestrial and epiphytic bromeliads could be acting as cysts reservoirs when environmental conditions like humidity degree are not suitable for ciliates. An outstanding observation was the record of the hymenostomatid *Glaucomides bromelicola* from *T. rothii*, which was one of the eight bromeliads where dry detritus and no water were collected due to the absence of precipitation the days before sampling. The cysts of this ciliate species has not been described yet, and Foissner (2013) established that *G. bromelicola* does not have the ability to produce this type of resistance phase of its life cycle when the bromeliad tank desiccates. However, its presence after rehydration of dry detritus, could be considered as indirect evidence that under unknown circumstances, *G. bromelicola* is able to encyst while waiting for more favorable conditions.

In the context of geographical distribution of ciliates in the Neotropics, we found that studies of alpha-diversity are scarce for this biogeographical region, and some countries in the Neotropics did not have any records. Of the total number of taxa identified at species level, 13 species showed a cosmopolitan distribution and six have a geographical distribution restricted to the Neotropics. Concerning bromeliads, in spite of their wide distribution in different Neotropical ecosystems, detailed studies about ciliates and bromeliads have been conducted only in few countries such as Brazil. For example, the gonostomatid *Gonostomum bromelicola* has only been recorded from its type locality (Foissner 2016), and for this reason, it has been considered a Gondwanan endemic species. Its presence in bromeliads from RBCC, supports the moderate endemicity model of Foissner (2008); however, the idea of a wider distribution on ciliates according to the geological evolution and split of Gondwanna and Laurasia can also be considered (Bourland 2017). Another example is the oxytrichid *Pattersoniella vitiphila*, a species only known from few localities in the Southern Hemisphere (Berger 1999), which has been recently observed in the Northern Hemisphere.

According to previous records, soil is the most common habitat of the ciliates species found in this study. Other common habitats in the Neotropics for this group of species include rivers, decaying bark, tank bromeliads, moss, tree litter, and biological crusts. In the case of ciliates that show specificity to inhabit bromeliads, both tank and tank-less, their geographical distribution matches the distribution of family Bromeliaceae. However, the existence of different distributional patterns of a single ciliate species or group of species within the Neotropical region is unknown. Our results represent the first records of ciliates in tank-less bromeliads and contribute to the knowledge about the biodiversity of the RBCC and the dry tropical forest, as well as to the general knowledge about ciliates that inhabit bromeliads in the Neotropics.

Acknowledgements

To Posgrado en Ciencias Biológicas, UNAM and National Council of Science and Technology (CONACYT) for the grant number 224627 to CDR. We thank J. H. Vega-Rivera for the permission to collect samples in the Reserve of the Biosphere Chamela-Cuixmala, IB-UNAM. Special thanks to Dr. Nettie McMiller (North Carolina Central University, Durham, USA) to improve this manuscript, Biól. M. Reyes-Santos for her technical assistance, and Mag. D. Méndez-Sánchez for the elaboration of the map.

References

Aladro-Lubel, M.A., Martínez-Murillo, M.E. & Mayén-Estrada, R. (1990) *Manual de ciliados psamófilos marinos y salobres de México*. Instituto de Biología, Universidad Nacional Autónoma de México, México, 172 pp.

Aladro-Lubel, M.A., Mayén-Estrada, R. & Reyes-Santos, M. (2006) *Listados Faunísticos de México XI. Registro Actualizado de Ciliados. Agosto, 2004*. Instituto de Biología, Universidad Nacional Autónoma de México, 97 pp.

Arévalo-Trear, R.E. (1967) *Sistemática y morfología de algunas especies de protozoarios edafícolas aislados de un tipo de suelo de andosol, del estado de Morelos, México.* Undergraduated thesis, Universidad Nacional Autónoma de México, 41 pp.

Benzing, D.H. (2000) *Bromeliaceae: profile of an adaptive radiation*. Cambridge University Press, New York, 655 pp. https://doi.org/10.1017/CBO9780511565175

Berger, H. (1999) *Monograph of the Oxytrichidae (Ciliophora, Hypotrichia).* Monographiae Biologicae 78, Dordrecht, Netherlands, 1079 pp.

Bourland, W. (2017) How far do ciliate flagships sail? A proposed Gondawanaland endemic species at anchor in Idaho soils. *Protist*, 168 (3), 352–361. https://doi.org/10.1016/j.protis.2017.04.002

Bovee, E. (1957) Protozoa of Amazonian and Andean waters of Colombia, South America. *Journal of Protozoology*, 4, 63–66. https://doi.org/10.1111/j.1550-7408.1957.tb02487.x

Buosi, P.R.B., Utz, L.R.P., de Meira, B.R., Segóvia da Silva, B.T., Lansac-Tôha, F.M., Lansac-Tôha, F.A.L. & Velho, L.F.M. (2014) Rainfall influence on species composition of the ciliate community inhabiting bromeliad phytotelmata. *Zoological Studies*, 53, 1–12. https://doi.org/10.1186/s40555-014-0032-4

Bütschli, O. (1887-1889) Protozoa. Abt. III. Infusoria und System der Radiolaria. *In*: Bronn, H.G. (Ed.), *Klassen und Ordnung des Thiers Reichs* Vol. 1, C.F. Winter, Leipzig, pp. 1089–2035.

Ceballos, G. & García, A. (1995) Conserving neotropical biodiversity: the role of dry forests in western Mexico. *Conservation Biology*, 9, 1349–1356.

Certes, A. (1891) Note sur deux infusoires nouveaux des environs de Paris. *Mémoires de la Société Zoologique de France*, 4, 536–541.

Cruz-Jiménez, G. (2017) *Riqueza de ciliados (Protozoa: Ciliophora) que habitan en* Campylopus pilifer *Brid. (Bryophyta) en un gradiente altitudinal en el estado de Oaxaca*. Undergraduated thesis, Universidad de la Sierra Juárez, Mexico, 69 pp.

Dragesco, J. & Dragesco-Kernéis, A. (1979) Ciliès muscicoles nouveaux ou peu connus. *Acta Protozoologica,* 18, 401–416.

Dragesco, J. & Dragesco-Kernéis, A. (1986) *Ciliés libres de l'Afrique intertropicale: introduction à la connaissance et à l'étude des Ciliés*. Editions de l'Orstom, Paris, 559 pp.

Dunthorn, M., Stoeck, T., Wolf, K., Breiner, H.W. & Foissner, W. (2012) Diversity and endemism of ciliates inhabiting Neotropical phytotelmata. *Systematics and Biodiversity,* 10 (2), 195–205. https://doi.org/10.1080/14772000.2012.685195

Durán-Ramírez, C.A., García-Franco, J.G., Foissner, W. & Mayén-Estrada, R. (2015) Free living ciliates from epiphytic tank bromeliads in Mexico. *European Journal of Prostistology*, 51, 15–33. https://doi.org/10.1016/j.ejop.2014.09.002

Enriques, P. (1908) Sulla morfologia e sistematica del genere *Colpoda*. *Archives de Zoologie Expérimentale et Générale,* 8, 1–15.

Espejo Serna, A. & López-Ferrari, A.R. (2005) Una nueva especie de *Tillandsia* (Bromeliaceae) del Occidente de México. *Acta Botánica Mexicana*, 72, 53–64. https://doi.org/10.21829/abm72.2005.1001

Espejo-Serna, A., López-Ferrari, A.R., Ramírez-Morillo, I., Holst, B.K., Luther, H. & Hill, W. (2004) Checklist of Mexican Bromeliaceae with notes on species distribution and levels of endemism. *Selbyana*, 25, 33–86.

Fernández-Galiano, D. & Calvo, P. (1992) Redescription of *Phacodinium metchnikoffi* (Ciliophora, Hypotrichida): general morphology and taxonomic position. *Journal of Protozoology*, 39 (4), 443–448. https://doi.org/10.1111/j.1550-7408.1992.tb04829.x

Foissner, W. (1987a) Soil protozoa: fundamental problems, ecological significance, adaptations in ciliates and testaceans,

bioindicators, and guide to the literature. *Progress in Protistology*, 2, 69–212.
Foissner, W. (1987b) Neue und wenig bekannte hypotriche und colpodide Ciliaten (Protozoa: Ciliophora) aus Böden und Moosen. *Zoologische Beiträgen N. F.*, 31 (2), 187–282.
Foissner, W. (1993) *Colpodea* (*Ciliophora*). Gustav Fischer Verlag. New York, 789 pp.
Foissner, W. (1995) Tropical protozoan diversity: 80 ciliate species (Protozoa, Ciliophora) in a soil sample from a tropical dry forest of Costa Rica, with descriptions of four new genera and seven new species. *Archiv für Protistenkunde,* 145, 37–79. https://doi.org/10.1016/S0003-9365(11)80300-3
Foissner, W. (1997) Soil ciliates (Protozoa: Ciliophora) from evergreen rain forests of Australia, South America and Costa Rica: diversity and description of new species. *Biology and Fertility of Soils*, 25, 317–339. https://doi.org/10.1007/s003740050322
Foissner, W. (1998) An updated compilation of world soil ciliates (Protozoa, Ciliophora), with ecological notes, new records, and descriptions of new species. *European Journal of Protistology*, 34, 195–235. https://doi.org/10.1016/S0932-4739(98)80028-X
Foissner, W. (2000) Notes on ciliates (Protozoa, Ciliophora) from *Espeletia* trees and *Espeletia* soils of the Andean Páramo, with descriptions of *Sikorops espeletiae* nov. spec. and *Fragmocirrus espeletiae* nov. gen., nov. spec. *Studies on Neotropical Fauna and Environment*, 35, 52–79. https://doi.org/10.1076/0165-0521(200004)35:1;1-M;FT052
Foissner, W. (2008) Protist diversity and distribution: some basic considerations. *Biodiversity and Conservation*, 17, 235–242. https://doi.org/10.1007/s10531-007-9248-5
Foissner, W. (2010) Life cycle, morphology, ontogenesis, and phylogeny of *Bromeliothrix metopoides* nov. gen., nov. spec., a peculiar ciliate (Protista, Colpodea) from tank bromeliads (Bromeliaceae). *Acta Protozoologica*, 49 (3), 159–193.
Foissner, W. (2013) Description of *Glaucomides bromelicola* n. gen., n. sp. (Ciliophora, Tetrahymenida), a macrostome-forming inhabitant of bromeliads (Bromeliaceae), including redescriptions of *Glaucoma scintillans* and *G. reniformis*. *Journal of Eukaryotic Microbiology* 60, 137–157. https://doi.org/10.1111/jeu.12016
Foissner, W. (2014) An update of basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa. *International Journal of Systematic and Evolutionary Microbiology*, 64, 271–292. https://doi.org/10.1099/ijs.0.057893-0
Foissner, W. (2016) Terrestrial and semiterrestrial ciliates (Protozoa, Ciliophora) from Venezuela and Galápagos. *Denisia*, 35, 1–912.
Foissner, W., Strüder-Kypke, M., van der Staay, G., Moon-van der Staay, S. & Hackstein, J. (2003) Endemic ciliates (Protozoa, Ciliophora) from tank bromeliads (Bromeliaceae): a combined morphological, molecular, and ecological study. *European Journal of Protistology*, 39, 365–372. https://doi.org/10.1078/0932-4739-00005
Foissner, W., Wolf, K.W., Yashchenko, V. & Stoeck, T. (2011) Description of *Leptopharynx bromelicola* n. sp. and characterization ofthe genus *Leptopharynx* Mermod, 1914 (Protista, Ciliophora). *Journal of Eukaryotic Microbiology*, 58, 134–151. https://doi.org/10.1111/j.1550-7408.2011.00532.x
García-Oliva, F., Maass, J. M. & Galicia, L. (1995) Rainstorm analysis and rainfall erosivity of a seasonal tropical region with a strong cyclonic influence in the Pacific Coast of Mexico. *Journal of Applied Meteorology*, 34, 2491–2498. https://doi.org/10.1175/1520-0450(1995)034<2491:RAAREO>2.0.CO;2
Givnish, T.J., Barfuss, M.H., Van Ee, B., Riina, R., Schulte, K., Horres, R., Gonsiska, P.A., Jabaily, R.S., Cray, D.M., Smith, J.A.C., Winter, K., Brown, G.K., Evans, T.M., Holst, B.K., Luther, H., Till, W., Zizka, G., Berry, P.E. & Sytsma, K.J. (2014) Adaptive radiation, correlated and contingent evolution, and net species diversification in Bromeliaceae. *Molecular Phylogenetics and Evolution* 71, 55–78. https://doi.org/10.1016/j.ympev.2013.10.010
Givnish, T.J., Millam, K. C., Berry, P.E. & Sytsma, K.J. (2007) Phylogeny, adaptive radiation, and historical biogeography of Bromeliaceae inferred from ndhF sequence data. *Journal of Systematic and Evolutionary Botany*, 23 (1), 3–26.
Gouda, E.J., Butcher, D. & Gouda, C.S. (2015) Encyclopaedia of Bromeliads, Version 3. University Botanic Gardens, Utrecht. Available from: http://encyclopedia.florapix.nl/ (accessed 27 November 2017)
Gmelin, J.F. (Ed.) (1790) *Caroli Lineé Systema Naturae per regna tria naturae, secundum classes, ordines, genere, species, cum characteribus differentiis, synonymis, locis*. Ed. 13, Leipzig, 500 pp.
Guggiari, M. & Peck, R. (2008) The bacterivorous ciliate *Cyclidium glaucoma* isolated from a sewage treatment plant: molecular and cytological descriptions for barcoding. *European Journal of Protistology*, 44 (3), 168–180. https://doi.org/10.1016/j.ejop.2007.11.004
Hardoim, E.L. & Heckman, C.W. (1996) The seasonal succession of biotic communities in wetlands of the tropical wet and dry climatic zone: IV. The free living sarcodines and ciliates of the Pantanal of Mato Grosso, Brazil. *International Review of Hydrobiology*, 81 (3), 367–384. https://doi.org/10.1002/iroh.19960810307
Hernández-Anaya, M. (1981) *Ciliados de una laguneta de los médanos cercanos al puerto de Veracruz.* Undergraduated thesis, Universidad Nacional Autónoma de México, México, 81 pp.

Kahl, A. (1926) Neue und wenig bekannte Formen der holotrichen und heterotrichen Ciliaten. *Archive für Protistenkunde*, 55, 197–438.
Küppers, G.C. & Claps, M.C. (2012a) Freshwater ciliates (Protozoa, Ciliophora) from Argentina: an annotated and updated compilation. *In*: Thangadurai, D., Busso, C.A., Abarca-Arenas, L.G. & Jayabalan, S. (Eds.), *Frontiers in Biodiversity Studies*. I.K. International Publishing House, New Delhi and Bangalore, India, pp. 61–100.
Küppers, G.C. & Claps, M.C. (2012b) Spatiotemporal variations in abundance and biomass of planktonic ciliates related to environmental variables in a temporal pond, Argentina. *Zoological Studies*, 51 (3), 298–313.
Küppers, G.C. & Claps, M.C. (2016) Diversity of freshwater ciliates (Protista) from Argentina. *Revista Brasileira de Zoociências*, 17 (1), 63–76.
Lee, J.J., Leedale, G.F. & Bradbury, P. (2000) *An illustrated guide to the Protozoa*. Vol. I. Society of Protozoologists, Kansas, 689 pp.
Lynn, D.H. (2008) *The ciliated protozoa: characterization, classification, and guide to the literature.* Springer, Dordrecht. Netherlands, 605 pp.
Madrazo-Garibay, M. & López-Ochoterena, E. (1982) Segunda lista taxonómica comentada de protozoarios de vida libre de México. *Revista Latinoamericana de Microbiología*, 24, 281–295.
Madrazo-Garibay, M. & López-Ochoterena, E. (1985) Protozoarios ciliados de México XXVI. Análisis morfológico y taxonómico de treinta y cinco especies de la laguna de Términos, Campeche. *Anales del Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México* 12, 199–212.
Maguire, Jr. B. (1971) Phytotelmata: biota and community structure determination in plant-held waters. *Annual Reviews in Ecology and Systematics*, 2, 439–464.
https://doi.org/10.1146/annurev.es.02.110171.002255
Maupas, E. (1883) Contribution à l'etude morphologique et anatomique des infusoires ciliés. *Archives de Zoologie Expérimentale et Générale* (Ser. 2), 11, 427–664.
Méndez-Sánchez, D. (2017*) Estudio taxonómico de ciliados de vida libre (Alveolata: Ciliophora) en cuerpos de agua dulce de dos regiones biogeográficas de México*. Master's thesis, Universidad Nacional Autónoma de México, México, 149 pp.
Mermod, G. (1914) Recherches sur la faune infusorienne des tourbieres et des eaux voisines de Sainte-Croix (Jura vaudois). *Revue Suisse de Zoologie*, 22, 31–114.
https://doi.org/10.5962/bhl.part.36669
Mondragón-Camarillo, L. (2011) *Estructura trófica de la comunidad de ciliados y flagelados en un suelo de cultivo contaminado con combustóleo de Jalacingo, Veracruz*. Master's thesis, Universidad Nacional Autónoma de México, México, 56 pp.
Morrone, J.J. (2017). *Neotropical biogeography: Regionalization and evolution*. CRC Press. Florida, 282 pp.
Müller, O.F. (1773) *Vermium terrestrium et fluviatilium, seu animalium infusorium, helminthicorum et testaceorum, non marinorum, succincta historia*. Heineck & Faber, Hafniae & Lipsiae, pp. l–30, 1–135.
Omar, A. & Foissner, W. (2011) Description of *Leptopharynx bromeliophilus* nov. spec. and *Leptopharynx australiensis* nov. spec. (Ciliophora, Nassulida). *Acta Protozoologica*, 50 (2), 89–103.
Omar, A. & Foissner, W. (2012a) Neotypification and ontogenesis of *Leptopharynx costatus costatus* Mermod, 1914. *Journal of Eukaryotic Microbiology*, 59 (3), 268–286.
https://doi.org/10.1111/j.1550-7408.2012.00620.x
Omar, A. & Foissner, W. (2012b) Description of *Leptopharynx brasiliensis* nov. spec. and *Leptopharynx costatus gonohymen* nov. subspec. (Ciliophora, Microthoracida). *European Journal of Protistology,* 48 (1), 30–47.
https://doi.org/10.1016/j.ejop.2011.07.002
Omar, A. & Foissner, W. (2014) Three new microthoracids (Ciliophora, Nassophorea) from Austria and Venezuela. *Acta Protozoologica*, 53, 295–311.
Pauleto, G.M., Velho, L.F.M., Buosi, P.R.B., Brão, A.F.S., Lansac-Tôha, F.A. & Bonecker, C.C. (2009) Spatial and temporal patterns of ciliate species composition (Protozoa: Ciliophora) in the plankton of the Upper Paraná River floodplain. *Brazilian Journal of Biology*, 69 (2), 517–527.
https://doi.org/10.1590/S1519-69842009000300007
Penard, E. (1922) *Études sur les infusoires d'eau douce.* Georg & Cie Ed., Genève, 331 pp.
Prowazek, S. von (1900) Protozoenstudien II. *Arbeiten aus dem Zoologischen Instituten der Universität Wien,* 12, 243–300.
Reyes?García, C., Mejia?Chang, M. & Griffiths, H. (2012) High but not dry: diverse epiphytic bromeliad adaptations to exposure within a seasonally dry tropical forest community. *New Phytologist*, 193 (3), 745–754.
https://doi.org/10.1111/j.1469-8137.2011.03946.x
Rico-Ferrat, G. (1990) Identificación de los protozoarios que habitan en la hojarasca de un bosque mesófilo en Gómez Farías, Tamaulipas, México. *Revista de la Sociedad Mexicana de Historia Natural*, 41, 33–36.
Rondello-Bonatti, T., Siqueria-Castro, I.C.V. & Bueno-Franco, R.M. (2016) Checklist of ciliated protozoa from surface water and sediment samples of Atibaia River, Campinas, São Paulo (Southeast Brazil). *Revista Brasileira de Zoociências*, 17 (1), 63–76.
Sigala-Regalado, I. (2011) *Diversidad de protozoos ciliados en cinco biotopos de cuevas en México*. Master's thesis, Universidad Nacional Autónoma de México, México, 130 pp.
Small, E.B. (1967) The Scuticociliatida, a new order of the class Ciliatea (phylum Protozoa, subphylum Ciliophora).

Transactions of the American Microscopical Society, 86 (4), 345–370.
https://doi.org/10.2307/3224258

Steffens, S. & Wilbert, N. (2002) Ciliates (Protozoa: Ciliophora) of selected ephemeral flushs on tropical inselbergs. *International Review of Hydrobiology*, 87 (4), 401–410.
https://doi.org/10.1002/1522-2632(200207)87:4<401::AID-IROH401>3.0.CO;2-A

Trejo, I. (2010). Las selvas secas del Pacífico mexicano *In*: Ceballos, G., Martínez, L., García, A., Espinoza, E., Creel, J.B. & Dirzo, R. (Eds.), *Diversidad, amenazas y áreas prioritarias para la conservación de las selvas secas del Pacífico de México*. EcoCiencia, S. C., CONANP, FCE, CONABIO, TELMEX, Telcel, WWF, México, pp. 42–51.

Capítulo II

Durán-Ramírez, C. A., Mayén-Estrada, R. & Romero-Niembro, V. M. 2019.

Ciliate community structure in bromeliads of different types of vegetation in eastern Mexico.

Acta Protozoologica 58 (3): 155-165.

ACTA
PROTOZOOLOGICA

Acta Protozool. (2019) 58: 155–165
www.ejournals.eu/Acta-Protozoologica
doi:10.4467/16890027AP.19.015.11916

Ciliate Community Structure in Bromeliads of Different Types of Vegetation in Eastern Mexico

Carlos Alberto DURÁN-RAMIREZ[1,2], Rosaura MAYÉN-ESTRADA[1], Víctor Manuel ROMERO-NIEMBRO[1]

[1] Laboratorio de Protozoología, Departamento de Biología Comparada, Facultad de Ciencias, Universidad Nacional Autónoma de México, Coyoacán, Mexico City, Mexico
[2] Posgrado en Ciencias Biológicas, Facultad de Ciencias, Universidad Nacional Autónoma de México

Abstract. To understand distributional and ecological aspects of ciliates living in tank bromeliads, we analyzed the ciliate community structure in fifteen different epiphytic and terrestrial bromeliad species from different types of vegetation. Sixty-nine samples were collected from plants of genera *Aechmea*, *Bromelia, Pseudalcantarea* and *Tillandsia* in seven localities in eastern Mexico during 2014 and 2015. The sampling localities covered an altitude gradient from 0 till 2 210 m ASL. We found 24 ciliate species and through the application of a principal component analysis, three clusters that correspond to several types of vegetation were obtained with regard to ciliate and bromeliad species. We recorded the largest number of ciliate species in localities of montane cloud forest, and also the largest number of ciliate species endemic to tank bromeliads, like *Glaucomides bromelicola*, inhabiting bromeliads from this forest. We observed the presence of ciliates in *Bromelia pinguin* that possesses a weakly developed phytotelm. The results of our study indicate that the species composition of ciliates inhabiting tank bromeliads depends on such correlated environmental factors like altitude ASL, temperature and type of vegetation.
Keywords: Neotropics, phytotelma, ciliates.

INTRODUCTION

Global diversity of ciliates still remains unknown, with at least a half of their estimated diversity undescribed. The lack of studies in many terrestrial, marine and limnetic ecosystems is one of the reasons that distributional patterns of ciliates at global and local scale remains strongly debated between protistologist (Foissner 1999, 2006).

Ciliates play an important role by grazing on bacterial populations in a wide variety of ecosystems, participating in nutrient cycling, and contributing in a significant way to the so called terrestrial microbial loop (Fenchel 1980, Clarholm 1985, Pomeroy et al. 2007). Studies of ciliate diversity from tank bromeliads are scarce and have been mainly carried out with a taxonomic focus (Foissner et al. 2003, Dunthorn et al. 2012, Durán-Ramírez and Mayén-Estrada 2018,

Address for correspondence: Carlos Alberto Durán-Ramírez, Laboratorio de Protozoología, Departamento de Biología Comparada, Facultad de Ciencias, Universidad Nacional Autónoma de México, Circuito ext. s/n, 04510 Coyoacán, Mexico City, Mexico; E-mail: carlosduran_88@hotmail.com

Durán-Ramírez et al. 2015). Many aspects of the ecology and distribution of bromeliad-associated ciliates in the Neotropics are almost unknown. Recently, Buosi et al. (2014, 2015) documented the importance of water to the establishment of ciliates in bromeliads where seasonality influenced their abundances, but they found no evidence of a spatial effect between plants at population level. Impoundments of water in tank bromeliads represent an ideal model to study ciliate ecology and their distributional patterns in Neotropical forests. For this reason, the distribution of ciliates in tank bromeliads at local scale and their community structure, can be elucidated through the comparison of different types of vegetation where bromeliads occur.

Many bromeliad species are so-called "tank bromeliads", that collect water in a central "tank" formed by the rosette of leaves and often in peripheral collections formed by leaf axils (Benzig 2000). Nadkarni (1994) considered tank bromeliads as keystone resources in the forest and the water impoundments that they form microecosystems termed "phytotelmata" (Maguire 1971).

The ciliate communities inhabiting the water of tank bromeliads, are composed of some species that show a cosmopolitan distribution and others are that considered as endemics to bromeliads (Foissner et al. 2003, Durán-Ramírez et al. 2015). Host specificity between ciliate species and bromeliads has not yet been demonstrated (Foissner et al. 2003).

The state of Veracruz, in eastern Mexico, shows a wide variety of types of vegetation and floristic richness (Rzedowski 1978) where almost one hundred species of bromeliad have been recorded (Espejo-Serna et al. 2005). The objective of our study was to analyze the free living ciliate community structure in different epiphytic and terrestrial tank bromeliad species, inhabiting in different types of vegetation in eastern Mexico. Our results contribute to the knowledge about ciliate diversity, ecology and biogeography, in bromeliad phytotelmata of the Neotropics.

MATERIALS AND METHODS

Area of study. We collected samples during December 2014, April and May of 2015 from seven localities in the state of Veracruz, eastern Mexico (Fig. 1), including a fragment of semideciduous tropical forest on coastal dunes along the coastal shore with only one locality; two localities with remnants of semideciduous tropical forest; two coffee plantations (one with remnants of semideciduous tropical forest and the other with remnants of montane cloud forest); a fragment of montane cloud forest, and also an ecotone between the montane cloud forest and pine forest; all localities included fragments of forest with some degree of perturbation, surrounded by urban and agricultural zones. Localities belong to the municipalities of Acajete (locality 1), Xalapa (locality 2), Coatepec (locality 3), Jalcomulco (locality 4), Tuzamapan (locality 5), and Actopan (localities 6 and 7) (Fig. 1, Table 1). Localities did not show a continuous forest cover, due to the high level of fragmentation, this affected the number of samples collected and distances separating neighbor localities.

Sample collection. We collected 69 samples of water with detritus in the rosettes of 15 bromeliad species of genera *Aechmea* Ruiz and Pav. 1793, *Bromelia* L. 1753*, Pseudalcantarea* (Mez) Pinzón and Barfuss, 2016 and *Tillandsia* L. 1753, with regard to their impoundment capacity and degree of development of the phytotelmata according to Benzig (2000). In each locality we collected five to 22 samples from different bromeliads depending on their availability (Table 1). We only collected samples from native terrestrial or epiphytic bromeliad species. Epiphytic plants were located about 1.5 m above ground. All plants contained water in their tanks and were separated from each other by a minimum distance of five meters. Samples of water and detritus were collected with new plastic pipettes and placed into sterilized Falcon tubes. The water temperature impounded inside the tank was measured using a thermometer (Taylor-5984). None of the plants were removed from their habitat. The bromeliads were photographed, and water samples maintained at room temperature.

Ciliate identification. To carry out taxonomical identification of ciliates, we analyzed each one of the 69 samples 48 hours after they were collected and at intervals of two days through the next two weeks. We established cultures in Petri dishes using some drops of the original sample, table water Evian ®, and wheat grains to stimulate bacterial growth (Foissner et al. 2003). We observed cytological characters of taxonomical importance *in vivo* (e.g. cell size and shape, position and shape of the cytostome, position and number of the contractile vacuoles) using bright field and differential interference contrast microscopy with a Nikon Labophot-2 microscope equipped with a Nikon Digital Sight DS-L15667 camera. We performed silver impregnation techniques according to the protocols of Foissner (2014), to reveal oral and somatic infraciliature, number and disposition of cirri, the silverline pattern, and nuclear apparatus. Microphotographs of some ciliates identified were taken with a Photo Microscope Olympus-Provis AX70 and Evolution MP5 megapix camera. We followed Czapik (1968), Curds (1975), Lee et al. (1985), Dragesco and Dragesco-Kernéis (1986), Foissner (1993, 2003, 2010, 2013), Foissner et al. (1991, 2011), Borror and Hill (1995), Berger (1999, 2006), Foissner and Stoeck (2011), Omar and Foissner (2011, 2013), and Fan et al. (2013) for species identification. Systematics is according to Lynn (2008).

Analysis of community structure. For the data analysis, we evaluated the similarity between localities and performed a Jaccard index analysis ($IJ_{A,B} = c/[a+b-c]$), where a is the number of species in the locality A, b is the number of species in the locality B, and c is the number of species shared between A and B, using a grouping analysis based on the UPGMA algorithm for presence/absence data (Moreno 2001; MVSP 3.22 Kovach Computing Services). Through a principal component analysis (PCA) we evaluated the association between a) the ciliate community structure and biotic factors like bromeliad species, and b) type of vegetation and abiotic factors like water temperature and altitude for each locality. For

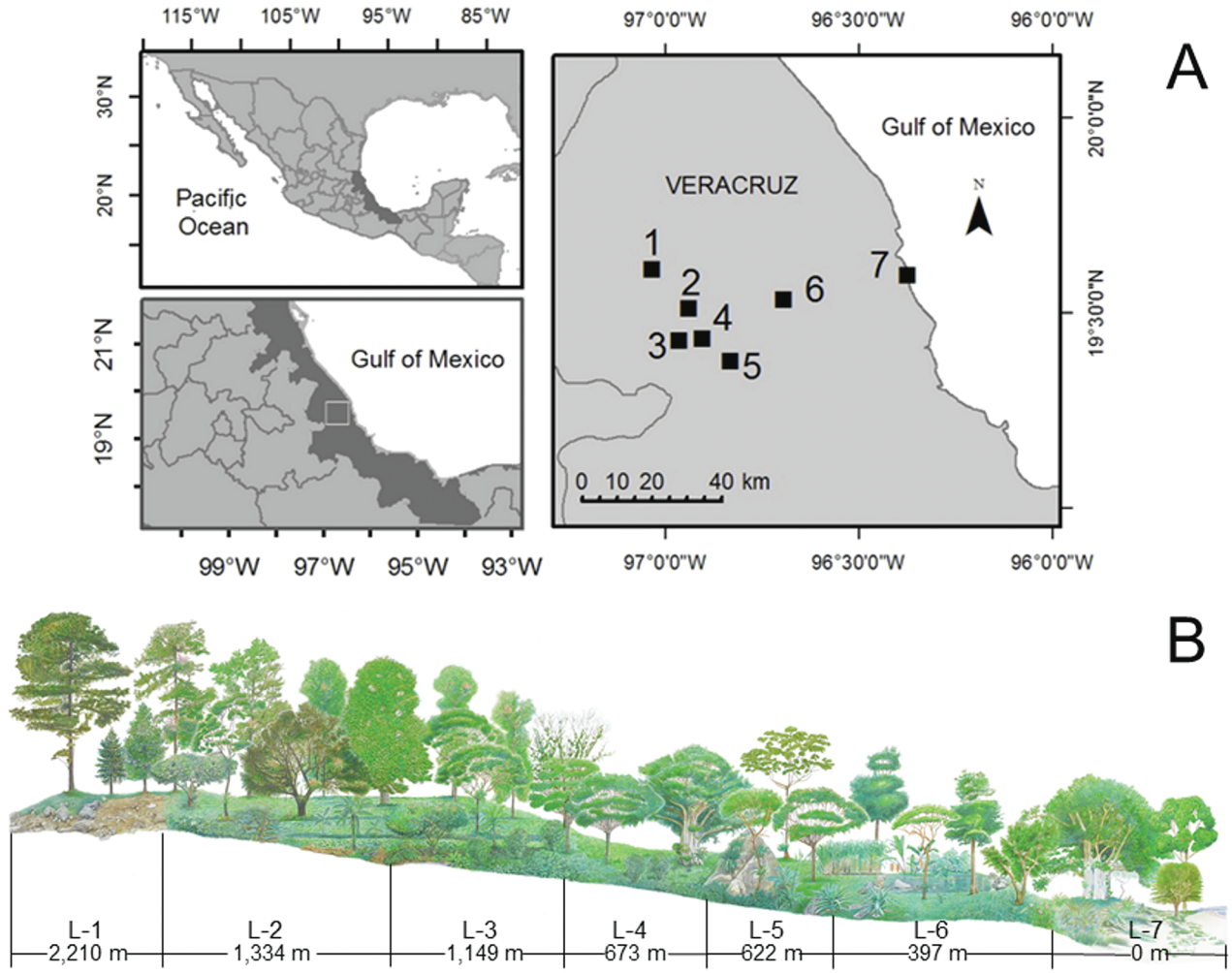


Fig. 1. A. Location of the seven localities of the study. B. Schematic representation of the vegetation from the mountain region to the seashore in east Veracruz, Mexico. L = locality, 1 = La Joya, Acajete; 2 = Santuario de Bosque de Niebla, Xalapa; 3 = Coffee plantation La Onza, Coatepec; 4 = Coffee plantation Arcos Vegas y Rincón de Yeguas, Tuzamapan; 5 = Tlacuitlapa, Jalcomulco; 6 = Unidad de Manejo Ambiental Nace El Río, Descabezadero, Actopan; 7 = Centro de Investigaciones Costeras La Mancha (CICOLMA), Actopan.

categorical variables, we assigned numerical values to include them into the analysis. To carry out the PCA, we applied the PRINCOMP procedure by using the statistical software package SAS University (SAS Institute, Cary, NC, U.S.A.). All graphics were plotted using the statistical software Prism 7.0 (Graph Pad Software, La Joya, CA, U.S.A.).

The five types of vegetation and agroecosystems were coded with values from 0 to 4, where 0 = semideciduous tropical forest, 1 = coffee plantation with remnants of semideciduous tropical forest, 2 = coffee plantation with remnants of montane cloud forest, 3 = montane cloud forest, and 4 = ecotone of montane cloud forest and pine forest. Bromeliad names were coded by using a number for each species according to their distribution in the localities.

RESULTS

Ciliate richness. The 69 bromeliads sampled belonged to 15 species of genera *Aechmea*, *Bromelia*, *Pseudalcantarea* and *Tillandsia* (Table 1). Mean values of water temperature impoundments are shown in Table 1 and Fig. 2. We found a total of 24 ciliate species, grouped in 17 genera (Tables 2–3, Fig. 4). The order Microthoracida showed the largest species richness, and *Leptopharynx* was the genus with most species (four). We recorded *Glaucomides bromelicola* (Fig. 4j) as the most frequent species present in 33 samples, and in 12 of the 15 bromeliad species. In contrast, nine

Table 1. Environmental data and ciliate species richness in the localities.

Locality	Vegetation type	Altitude (m ASL)	n	ATW (°C)	Bromeliad species
1	PF	2,210	10	12	T2 (e-IV), Tm (e-IV), Ty (e-IV)
2	MCF	1,334	22	17.6	Td (e-IV), Ts (e-IV), Tu (e-IV), Pv (e-IV)
3	C-MCF	1,149	10	16.7	Th (e-IV), Ti (e-IV)
4	C-MCF	673	5	20.6	Ab (e, t-III), Am (t-III)
5	SDTF	622	7	21	Pg (t-IV), T1(e-IV), Ab (e-III)
6	SDTF	397	5	20.4	Pg (t-IV), Ab (e-III)
7	SDTF	0	10	22.9	Tc (e-V), Bp (t-I)

Abbreviations of bromeliad species: Ab = *Aechmea bracteata*, Am = *Aechmea mexicana*, Bp = *Bromelia pinguin,* Pg = *Pseudalcantarea grandis*, Pv = *Pseudalcantarea viridiflora,* Tc = *Tillandsia concolor,* Td = *Tillandsia deppeana*, Th = *Tillandsia heterophylla*, Ti = *Tillandsia limbata*, Tm = *Tillandsia macrochlamys*, Tu = *Tillandsia multicaulis*, Ts = *Tillandsia* sp., Ty = *Tillandsia gymnobotrya*, T1 = *Tillandsia* sp.1, T2 = *Tillandsia* sp.2, e = epiphyte, t = terrestrial, I-V = ecological type according to Benzig (2000), ATW = Average temperature of water, SDTF = Semideciduous tropical forest, C = Coffee plantation, MCF = Montane cloud forest, PF = *Pinus* forest, n = number of collected samples.

Table 2. Records based on presence – absence of ciliate species from bromeliads in the localities.

Ciliate species	T. H.	L1	L2	L3	L4	L5	L6	L7
Anteholosticha sp.		+						
Bromeliophrya brasiliensis Foissner, 2003*	B		+	+				
Bromeliothrix metopoides Foissner, 2011	B		+	+	+		+	+
Chilodonella uncinata (Ehrenberg, 1838)	S, T		+	+	+		+	
Colpoda cucullus (Müller, 1773)	S, T	+	+	+			+	+
Colpoda maupasi Enriques, 1908	S, T		+	+		+	+	+
Cotterillia bromelicola Foissner & Stoeck, 2011	B	+	+					
Drepanomonas revoluta Penard, 1922	S, T		+	+				
Euplotopsis sp.								+
Frontonia pusilla Fan *et al.,* 2013*	M							+
Glaucomides bromelicola Foissner, 2013	B	+	+	+	+	+		
Halteria spp.		+	+	+			+	+
Lambornella spp.		+	+	+	+	+	+	
Leptopharynx australiensis Omar & Foissner, 2011*	T							+
Leptopharynx bromelicola Foissner *et al.,* 2011	B		+					
Leptopharynx bromeliophilus Omar & Foissner, 2011	B	+	+	+				
Leptopharynx spp.		+	+	+		+		
Oxytricha sp.								+
Paracolpoda steinii (Maupas, 1883)	S, T		+					+
Peritrichia 1		+						
Peritrichia 2							+	
Peritrichia telotroch								+
Tetrahymena spp.			+	+		+		
Vorticella sp.								+
Total of species per locality		9	15	12	4	5	7	11

*New record in Mexico.
T.H. = Type of habitat of previous records: B = bromeliads, S = semiterrestrial, T = terrestrial, M = mangrove.

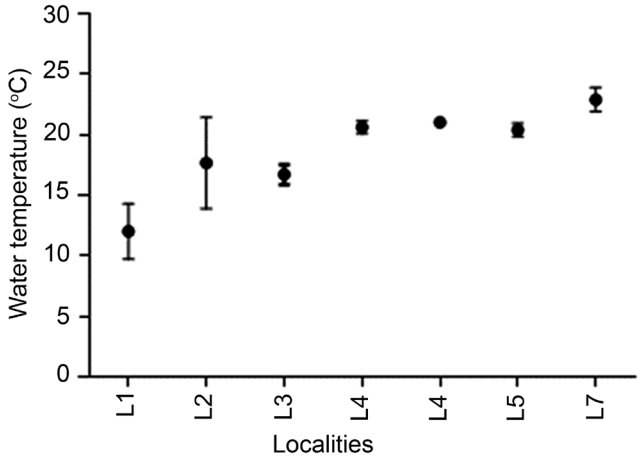


Fig. 2. Average of water temperature of the samples in relation to the localities were samples were collected. Bars indicate standard deviation.

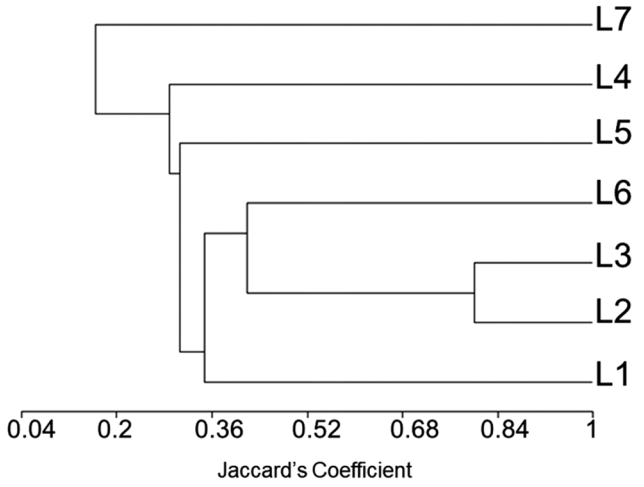


Fig. 3. Dendogram of the Jaccard's similarities among localities based on the unweighted pair-group method analysis (UPGMA). For the name of the localities see table 1.

ciliate species were observed only from a single bromeliad species (Tables 2–3). *Lambornella* spp. (Fig. 4h) were observed in almost all the localities with exception to locality 7. None of the ciliate species was present in all the 69 samples. The mean number of ciliate species was 9.1 per locality, and 2.8 per plant. Each ciliate species was recorded in seven samples on average (Table 2). Eleven species were only present in one or two samples. Ciliates were not detected in 20 percent of the samples.

Ciliate community structure according to localities. Ciliate community structure was different between localities. We found that locality 2 showed the highest richness with 15 species in the fragment of montane cloud forest in *Pseudalcantarea viridiflora, Tillandsia deppeana*, *T. multicauilis*, and *Tillandsia* sp., followed by localities 3 and 7 with 12 and 11 ciliate species respectively. Epiphytic bromeliads of the pine forest in locality 1 showed nine species, locality 6 seven species, locality 5 five species, and locality 4 had the lowest number of species, four species in *Aechmea bracteata* and *A. mexicana* (Table 2).

From localities 2 to 6 we observed most of the species that are considered endemics of tank bromeliads, i.e. *Bromeliophrya brasiliensis, Bromeliothrix metopoides, Leptopharynx bromelicola, L. bromeliophilus* and *Glaucomides bromelicola*. With the Jaccard similarity analysis, we obtained a maximum similarity value of 0.80 between localities 2 and 3, which corresponded to fragment of montane cloud forest, and the coffee plantation with remnants of this type of forest. The rest of localities showed similarity values < 0.5 (Fig. 3).

The PCA evaluated the association between ciliate community structure related to biotic (bromeliad species and type of vegetation) and abiotic factors (water temperature and elevation) considered in the study. Three principal components were retained and explained together 94.65 percent of the total variation within the data set. The first component explained 62.94 percent of the total variation, and showed a relation between biotic and abiotic factors, where the type of vegetation, bromeliad identity and elevation showed high positive loads to the first axis of variation. In contrast, water temperature showed high loads but was negatively related to the same axis. The second eigenvector only showed high positive loads for ciliate richness in each sample, being the second principal component that showed the ciliate community structure (Fig. 5A). Figure 5B showed that water temperature and type of vegetation were positively related with high loads to the third principal component, unlike ciliate community structure and elevation because of their low and negative correlation to this component. The scores of principal components 1 and 2 for the localities (Fig. 5B), and the type of vegetation and ciliate community structure (Fig. 5C), showed the association pattern between variables and components. In addition to the observed pattern of point dispersal (Fig. 5B), the three clustered groups correspond to each one of the types of vegetation, and entailed their separation from the axis 1 (Fig. 5C).

Semideciduous tropical and pine forest are clearly separated from montane cloud forest and coffee lands

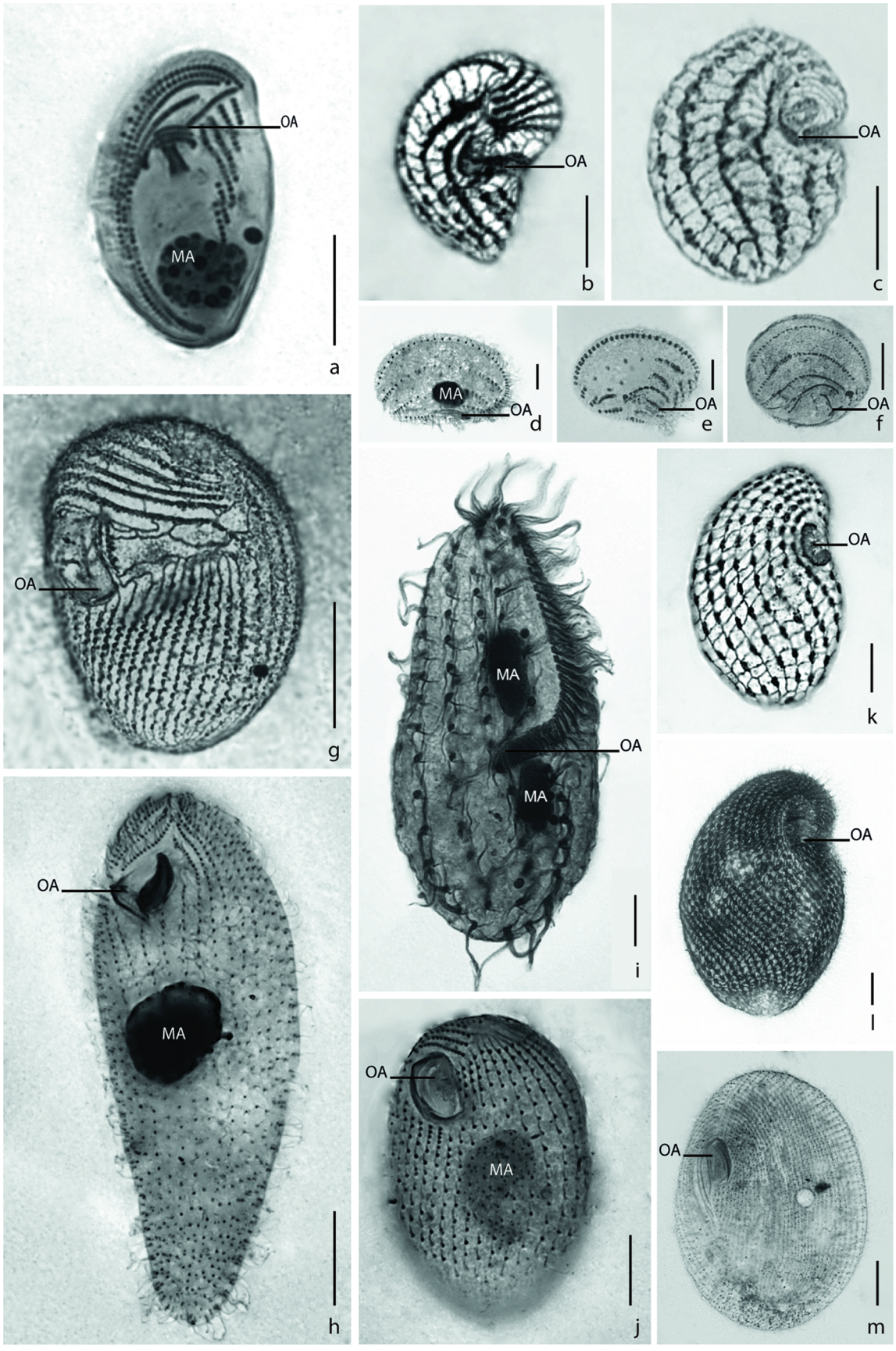

OA
MA
a
OA
b
OA
c
MA
OA
d
OA
e
OA
f
OA
g
MA
OA
i
OA
k
OA
MA
h
OA
l
OA
MA
j
OA
m

Fig. 4. Ciliates from the tank bromeliads after dry silver nitrate impregnation (b–c, e–g, k–m), and after protargol method (a, d, h–1j). a. *Chilodonella uncinata*, b. *Bromeliothrix metopoides*, c. *Paracolpoda steinii*, d. *Leptopharynx australiensis*, e. *L. bromeliophilus*, f. *L. bromelicola*, g. *Bromeliophrya brasiliensis*, h. *Lambornella* sp., i. *Cotterillia bromelicola*, j. *Glaucomides bromelicola*, k. *Colpoda maupasi*, l. *C. cucullus*, m. *Frontonia pusilla*. MA: macronucleus, OA: oral apparatus. Scale bars: 10 µm.

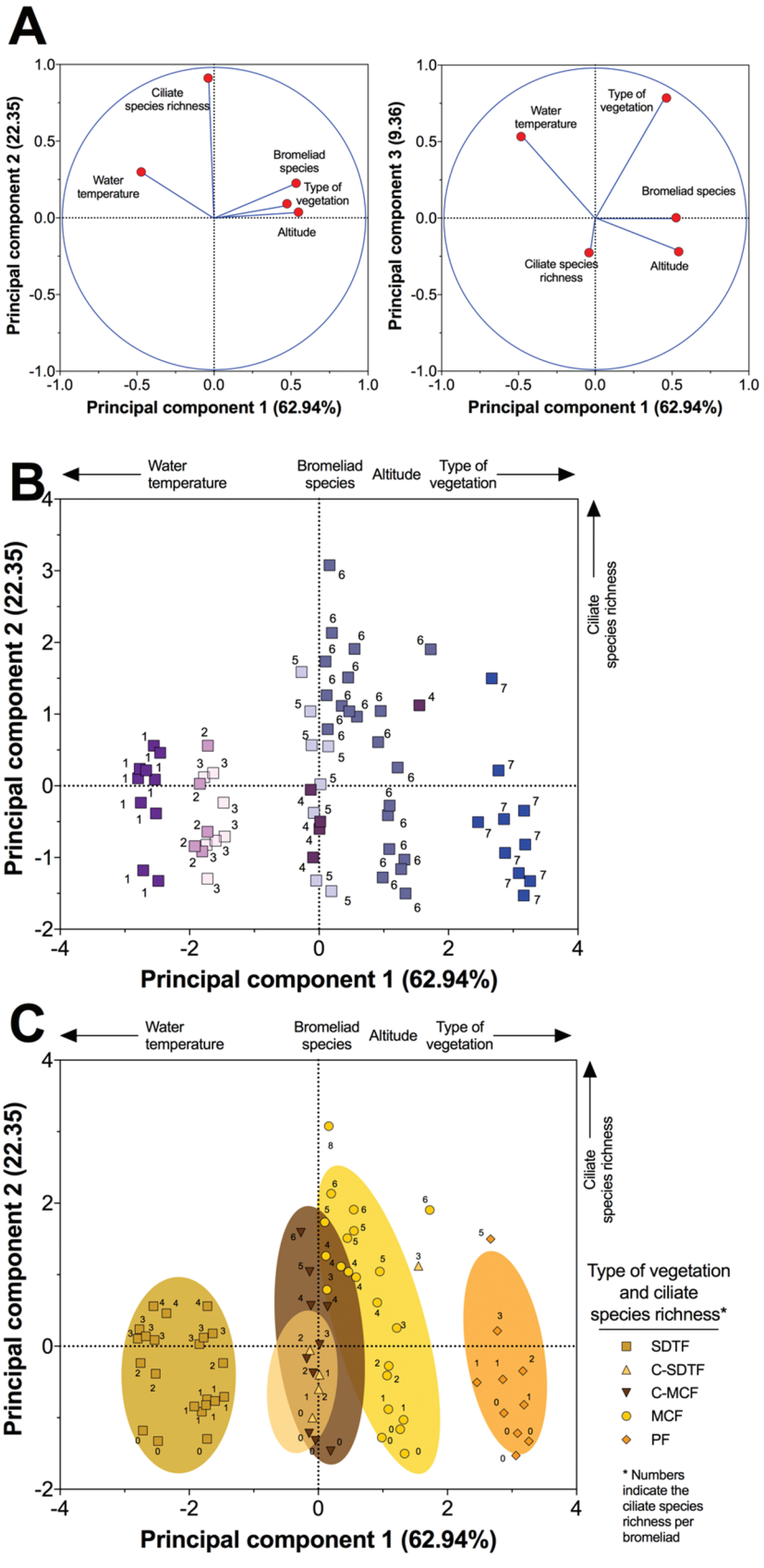


Fig. 5. A. Trait loadings of retained components in the PCA axes 1 and 2, (B) for each sampling carried out in the seven localities, and (C) for vegetation type and ciliate species richness according to the principal components of model A, of an ordination based on species richness, two continuous and two categorical functional traits of 24 ciliate species at Eastern Veracruz, Mexico. Model C shows prediction ellipses at 95% confidence interval to delimitate the vegetation types. Numbers in B refer to the localities. SDTF = Semideciduous tropical forest, C = Coffee plantation, MCF = Montane cloud forest, PF = *Pinus* forest.

showed the higher ciliate species richness. Each one of the sampled bromeliads and their respective number of ciliate species were represented by the set of points that are distributed in the axis 2 (Fig. 5C). The bromeliads with a larger ciliate species richness showed higher positive scores in axis 2.

DISCUSSION

Ciliate species composition, geographical distribution and their ecological aspects in tank bromeliads remain poorly understood. Our results indicate that ciliate species composition in bromeliads have local patterns of geographical distribution in relation to the type of vegetation in this part of the Neotropics. We found that species richness was larger at the montane cloud forest and ciliate communities have different species composition.

Due to the absence of specificity between ciliates-bromeliads, we did not consider the plant identity for the sampling; moreover, with exception of two bromeliad species, there was no single species with a continuous distributional pattern along the mountains from this region, however, the bromeliad distribution varies according to the type of vegetation (Carvajal-Hernández and Krömer 2015, Mondragón-Chaparro et al. 2006).

The PCA showed that more than 85 percent of the variation was explained by the principal component 1 and 2 (Fig. 5A), which means that ciliate species composition was influenced by the temperature of the water in the phytotelmata, altitude above sea level and type of vegetation. Almost all bromeliads species were distributed in only one type of vegetation (Fig. 5B), and ciliate species composition was different according to the three clusters that represent the major types of vegetation in the study, i.e. semideciduous tropical forest, montane cloud forest and pine forest (Fig. 5C).

Previous studies of ciliates in tank bromeliads in the Neotropics have documented higher number of species. For example, 61 species were recorded in *Tillandsia heterophylla* where the order Colpodida showed the largest number of species in Mexico (Durán-Ramírez et al. 2015). Buosi et al. (2014, 2015) observed 92 species and a high diversity of the order Hymenostomatida. They analyzed the effect of the seasonality and location of a population of *Aechmea distichantha* along the margins of River Paraná in Brazil. They suggested that their results were influenced by the proximity of the bromeliads to the river, where various freshwater ciliate species were able to colonize the plants along the river bank.

Eleven of the 24 species in the present study were only observed in one or two samples, and ciliates were undetectable in 20 percent of samples. Although most of the bromeliads were colonized by ciliates, their presence could be considered as part of the so-called rare biosphere, because they probably cannot establish populations that persist through time but have an unknown ecological significance (Weisse 2014). Patchy distribution was observed in ciliate communities from terrestrial and semiterrestrial environments in South America (Foissner 2016) and contrasts with other ciliate communities in tank bromeliads in the Neotropics. For example, an average of seven ciliate species were observed in bromeliads from central Mexico (Durán-Ramírez et al. 2015). In Brazil, Buosi et al. (2014, 2015) observed from 13 to 15 species per sample, where *Paracolpoda steinii* and *Cyclidium glaucoma* were the most frequent, and 50 species was the largest number that have been recorded from a single bromeliad, in north Venezuela (Foissner 2016). In the present work the low similarity of species richness between localities, with exception to localities 5 and 6, was consistent with the results from Buosi et al. (2015), who found that the species composition in the ciliate communities between geographically proximate bromeliads do not have a considerable similarity. Thus, it suggests that the composition of the ciliate communities from tank bromeliads show variations at spatial and temporal scale in the Neotropics.

As a consequence of differences of microhabitats conditions provided by the plants, by comparing previous results of studies carried out in other regions of the Neotropics, our results exhibit some differences. Foissner (2016) found 50 ciliate species inhabiting four plants from a montane cloud forest, in comparison to the 15 species from 22 bromeliads of locality 2 with the same vegetation. Buosi et al. (2014, 2015) reported 92 ciliate species from 72 individuals of *Aechmea distichantha* from rocky walls of the Paraná River, Brazilian Atlantic forest; in the present work, we found 11 species in 10 plants from a fragment of a similar tropical vegetation (locality 7).

The high diversity of tank bromeliads in some regions of the Neotropics makes it possible to collect samples from different genera and species within the same area, and to compare ciliate communities in each plant. In the present study, tank bromeliads of the gen-

era *Pseudalcantarea* and *Tillandsia* were common in humid mountain regions. A remarkable example is *Pseudalcantarea grandis*, a tank bromeliad that possesses one of the largest phytotelmata in the Neotropics, with a high capacity to accumulate more than ten liters of rain water (Benzig 2000). We observed that the ciliate community in *P. grandis* was composed of freshwater ciliate species like *Halteria* spp., terrestrials like *Colpoda maupasi*, and some bromeliad endemic ciliates like *Glaucomides bromelicola*. Moreover, the results (Table 3) reinforce the idea of the absence of host specificity between ciliates and bromeliads, mentioned by Foissner et al. (2003). According to Weisse et al. (2013b), *G. bromelicola* is one of the most common species in this type of microhabitat due to its bactivory and feeding on heterotrophic flagellates of genus *Polytomella*, explaining our observation of this ciliate species in almost half of the samples in this study.

The knowledge of ecology and distribution of other ciliate species endemic to tank bromeliads observed in the present study is still incomplete. An interesting example is *Bromeliothrix metopoides*, widely distributed in the Neotropical region from Mexico to Chile (Weise et al. 2013a). Foissner (2010) and Buosi et al. (2014, 2015) recorded *B. metopoides* in bromeliads from Brazilian forests at altitudes below 300 m ASL. By contrast, Durán-Ramírez et al. (2015) observed this ciliate in bromeliads from a montane cloud forest in Mexico above 1200 m ASL, suggesting that *B. metopoides* inhabits in bromeliads of many types of vegetation at different altitudes along the Neotropics. The endemicity of *B. metopoides* to bromeliads has been explained by its unusual narrow ecological niche given by its specific diet, based on bacteria and flagellates, its complex polymorphic life cycle, its ability to encyst, and its type *r* population strategy (Weisse et al. 2013a, b).

Cotterillia bromelicola (Foissner and Stoeck 2011) is known only from its type locality in Mexico and one site in Costa Rica (Durán-Ramírez et al. 2015, Foissner 2016). In the present study, *C. bromelicola* was observed in *T. gymnobotrya* (from pine forest) and *Tillandsia* sp. (from montane cloud forest), suggesting that, although it can inhabit different bromeliad species, its distribution in this part of the Neotropics is restricted to mountain forests.

We observed the presence of ciliates in *Bromelia pinguin*, a species with a weakly developed phytotelm. This cespitose terrestrial species of morphology type I, is characterized by its almost null capacity to accumulate rain water due to its foliar architecture (Benzig 2000). Thus, at least some type I bromeliads as well as those with well-developed phytotelmata (morphology types III and IV), can host ciliate communities. The recovery of *Frontonia pusilla* (Fan et al. 2013), described from a mangrove in Southern China, in *Bromelia pinguin* was unexpected. Its presence may be attributed to the substrate on which this bromeliad grows (i.e. coastal dunes) in this region of the Gulf of Mexico.

Ciliates are preyed by metazoan populations inhabiting bromeliads and other phytotelmata. Wiackowski and Kocerba-Soroka (2017) concluded that the presence/absence of predators (harpacticoid copepods) affects ciliate community structure of the phytotelmata of *Calathea* and *Heliconia*. We observed ants in association with some bromeliad species. These insects might also influence the composition of the protist community through the transport and accumulation of detritus (Carrias et al. 2012).

Regarding the habitat where ciliate species have been previously observed, six species are considered as proper inhabitants of tank bromeliads and six were terrestrial or semiterrestrial (Foissner 1998, 2016; Foissner et al. 2003; Omar and Foissner 2011). Moreover, *Frontonia pusilla* and *L. australiensis* were observed for the first time inhabiting bromeliads in the Neotropics and both are new records for Mexico.

In our study, the number of samples collected at some localities, specially locality 2, could have influenced the high ciliate species richness observed. In addition, Carrias et al. (2012) studying bromeliads in French Guyana, documented that detritus concentration, plant architecture and light incidence were the main factors affecting protist diversity. Fragmentation, sampling effort, effect of area and microclimatic variations may also influence species richness (Rahbek 1995). However, most of the localities in the current study were characterized by various degrees of anthropogenic ecological disturbance including deforestation and agriculture that may produce unknown effects on ciliate community structure in bromeliads. Further studies are needed on the taxonomy, ecology, and distribution of ciliates inhabiting tank bromeliads in the Neotropical region in order to better identify factors, which determine ciliate community structure in these unique habitats.

Acknowledgements: To Dra. Blanca Pérez Uz, Universidad Complutense de Madrid for improving the manuscript. From Facultad de Ciencias, UNAM, to Biól. Margarita Reyes for their technical assistance in laboratory, to Mag. Daniel Espinosa Diaz for the statistical analysis, and to Mag. Aldi de Oyarzábal for the elaboration of the

Table 3. Presence and ciliate species richness and the bromeliad species where they were recorded.

Ciliate species / Bromeliad species	Ab	Am	Bp	Pg	Pv	Tbc	Tc	Td	Ty	Ti	Tm	Tu	Ts	T1	T2	TS
Anteholosticha sp.									+							1
Bromeliophrya brasiliensis						+		+					+			3
Bromeliothrix metopoides	+					+	+						+			4
Chilodonella uncinata	+	+		+	+	+		+					+			7
Colpoda cucullus	+		+			+	+	+	+	+			+			8
Colpoda maupasi	+		+	+		+	+						+			6
Cotterillia bromelicola									+				+			2
Drepanomonas revoluta						+							+			2
Euplotopsis sp.			+													1
Frontonia pusilla			+													1
Glaucomides bromelicola	+	+		+	+	+		+	+		+	+	+	+	+	12
Halteria spp.			+	+		+					+	+	+			6
Lambornella spp.	+	+		+	+	+		+	+	+		+	+	+		11
Leptopharynx australiensis			+													1
Leptopharynx bromelicola												+	+			2
Leptopharynx bromeliophilus										+		+	+		+	4
Leptopharynx spp.	+					+					+		+			4
Oxytricha sp.			+													1
Paracolpoda steinii			+										+			2
Peritrichia 1									+							1
Peritrichia 2			+													1
Peritrichia telotroch				+												1
Tetrahymena spp.				+				+		+		+	+			5
Vorticella sp.			+													1
Total of species	7	3	10	7	3	10	3	6	6	4	3	6	15	2	2	

For abbreviations of bromeliad species, see table 1. TS = Total bromeliad species where a given ciliate has been recorded.

scientific illustration. To Mag. Daniel Méndez for the elaboration of the map. We thank Mag. Adriana Rojas, Centro de Investigaciones Costeras La Mancha (CICOLMA), and Café La Onza for their permission to sampling. To Dr. W. Bourland, Boise State University, U.S.A. for his comments and English grammar revision.

REFERENCES

Benzing D. H. (2000) Bromeliaceae: Profile of an adaptive radiation. Cambridge University Press, New York

Berger H. (1999) Monograph of the Oxytrichidae (Ciliophora, Hypotrichia). Monographiae Biologicae 78, Dordrecht

Berger H. (2006) Monograph of the Urostyloidea (Ciliophora, Hypotricha). Monographiae Biologicae 85, Dordrecht

Borror A. C., Hill B. F. (1995) The order Euplotida (Ciliophora): taxonomy, with division of *Euplotes* into several genera. *J. Eukaryot. Microbiol.* **42:** 457–466

Buosi P. R. B., Utz L. R. P., De Meira B. R., Segóvia da Silva B. T., Lansac-Tôha F. M., Tôha F. A. L., Velho L. F. M. (2014) Rainfall influence on species composition of the ciliate community inhabiting bromeliad phytotelmata. *Zool. Stud.* **53:** 32

Buosi P. R. B., Cabral A. F., Utz L. R. P., Vieira L. C. G., Velho L. F. M. (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

Carrias J. F., Brouard O., Leroy C., Régis-Céréghino R., Pélozuelo L., Dejean A., Corbara B. (2012) An ant-plant mutualism induces shifts in the protist community structure of a tank-bromeliad. *Basic Appl. Ecol.* **13:** 698–705

Carvajal-Hernández C. I., Krömer T. (2015) Riqueza y distribución de helechos y licofitos en el gradiente altitudinal del Cofre de Perote, centro de Veracruz, México. *Bot. Sci*. **93:** 601–614

Clarholm M. (1985) Interactions of bacteria, protozoa and plants leading to mineralization of soil nitrogen. *Soil Biol. Bioch.* **17:** 181–187

Curds C. R. (1975) A guide to the species of the genus *Euplotes* (Hypotrichida, Ciliatea). *Bull. Br. Mus. Nat. Hist. Zool.* **28:** 1–61

Czapik A. (1968) La famille Tetrahymenidae et son importance dans la systématique et l'evolution des ciliés. *Acta Protozool.* **5:** 315–357

Dragesco J., Dragesco-Kernéis A. (1986) Ciliés libres de l'Afrique intertropicale. Introduction à la connaissance et à l'étude des ciliés. Faune tropicale vol. 26, Éditions de l'orstom, Paris

Dunthorn M., Stoeck T., Wolf K., Breiner H. W., Foissner W. (2012) Diversity and endemism of ciliates inhabiting neotropical phytotelmata. *System. Biodivers.* **10:** 195–205

Durán-Ramírez C. A., Mayén-Estrada R. (2018). Ciliate species from tank-less bromeliads in a dry tropical forest and their geographical distribution in the Neotropics. *Zootaxa.* **4497:** 241–257

Durán-Ramírez C. A., García-Franco J. G., Foissner W., Mayén-Estrada R. (2015) Free living ciliates from epiphytic tank bromeliads in Mexico. *Eur. J. Protistol.* **51:** 15–33

Espejo-Serna A., López-Ferrari A., Ramírez-Morillo I. (2005) Bromeliaceae. *Flora de Veracruz* **136:** 1–307

Fan X., Lin X., Liu W., Xu Y., Al-Farraj S. A., Al-Rasheid K. A. S., Warren A. (2013) Morphology of three new marine *Frontonia* species (Ciliophora; Peniculida) with notes on the phylogeny of this genus. *Eur. J. Protistol.* **49:** 312–323

Fenchel T. (1980) Suspension feeding in ciliated protozoa: feeding rates and their ecological significance. *Microb. Ecol.* **6:** 13–25

Foissner W. (1993) Colpodea (Ciliophora). G. Fischer Verlag, New York

Foissner W. (1998) An updated compilation of world soil ciliates (Protozoa, Ciliophora), with ecological notes, new records, and descriptions of new species. *Eur. J. Protistol.* **34:** 195–235

Foissner W. (1999) Protist diversity: estimates of the near-imponderable. *Protist.* **150:** 363–368

Foissner W. (2003) Morphology and ontogenesis of *Bromeliophrya brasiliensis* gen. n., sp. n., a new ciliate (Protozoa: Ciliophora) from Brazilian tank bromeliads (Bromeliaceae). *Acta Protozool.* **42:** 55–70

Foissner W. (2006) Biogeography and dispersal of microorganisms: a review emphasizing protists. *Acta Protozool.* **45:** 111–136

Foissner W. (2010) Life cycle, morphology, ontogenesis, and phylogeny of *Bromeliothrix metopoides* nov. gen., nov. spec., a peculiar ciliate (Protista, Colpodea) from tank bromeliads (Bromeliaceae). *Acta Protozool.* **49:** 159–193

Foissner W. (2013) Description of *Glaucomides bromelicola* n. gen., n. sp. (Ciliophora, Tetrahymenida), a macrostome-forming inhabitant of bromeliads (Bromeliaceae), including redescriptions of *Glaucoma scintillans* and *G. reniformis*. *J. Eukaryot. Microbiol.* **60:** 137–157

Foissner W. (2014) An update of basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa. *Int. J. Syst. Evol. Microbiol.* **64:** 271–292

Foissner W. (2016) Terrestrial and semiterrestrial Ciliates (Protozoa, Ciliophora) from Venezuela and Galápagos. *Denisia*. **35:** 1–912

Foissner W., Stoeck T. (2011) *Cotterillia bromelicola* nov. gen., nov. spec., a gonostomatid ciliate (Ciliophora, Hypotricha) from tank bromeliads (Bromeliaceae) with de novo originating dorsalkineties. *Eur. J. Protistol.* **47:** 29–50

Foissner W., Blatterer H., Berger H., Kohmann F. (1991) Taxonomische und ökologische revision des saprobiensystems. Band I: Cyrtophorida, Oligotrichida, Hypotrichia, Colpodea. Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft 1/91. München

Foissner W., Strüder-Kypke M., Van Der Staay G., Moon-Van Der Staay S., Hackstein J. (2003) Endemic ciliates (Protozoa, Ciliophora) from tank bromeliads (Bromeliaceae): a combined morphological, molecular, and ecological study. *Eur. J. Protistol.* **39:** 365–372

Foissner W., Wolf K. W., Yashchenko V., Stoeck T. (2011) Description of *Leptopharynx bromelicola* n. sp. and characterization of the genus *Leptopharynx* Mermod, 1914 (Protista, Ciliophora). *J. Eukaryot. Microbiol.* **58:** 134–151

Lee J. J., Leedale G. F., Bradbury P. (1985) An Illustrated Guide to the Protozoa. Society of Protozoologists, Kansas

Lynn D. H. (2008) The ciliated protozoa: characterization, classification, and guide to the literature. Springer, Dordrecht

Maguire Jr. B. (1971) Phytotelmata: biota and community structure determination in plant-held waters. *Annu. Rev. Ecol. Syst.* **2:** 439–464

Mondragon-Chaparro D., Villa-Guzmán D. M., Escobedo-Sarti G. J., Franco-Méndez A. D. (2006) La riqueza de bromelias a lo largo de un gradiente altitudinal en Santa Catarina Ixtepeji, Oaxaca, México. *Naturaleza y Desarrollo.* **4:** 13–16

Moreno C. E. (2001) Métodos para medir la biodiversidad, Vol. 1. M&T-Manuales y Tesis SEA, Zaragoza

Nadkarni N. M. (1994) Diversity of species and interactions in the upper tree canopy of forest ecosystems. *Am. Zool.* **34:** 70–78

Omar A., Foissner W. (2011) Description of *Leptopharynx bromeliophilus* nov. spec. and *Leptopharynx australiensis* nov. spec. (Ciliophora, Nassulida). *Acta Protozool*. **50:** 89–103

Omar A., Foissner W. (2013) Description of two new *Drepanomonas* taxa and an account on features defining species in *Drepanomonas* Fresenius, 1858 (Ciliophora, Microthoracida). *Eur. J. Protistol.* **49:** 420–437

Pomeroy L. R., Williams P. J., Azam F., Hobbie J. E. (2007) The microbial loop. *Oceanography*. **20:** 28–33

Rahbek C. (1995) The elevational gradient of species richness: a uniform pattern? *Ecography.* **18:** 200–205

Rzedowski J. (1978) Vegetación de México. Limusa, México

Weisse T. (2014) Ciliates and the rare biosphere-community ecology and population dynamics. *J. Eukaryot. Microbiol.* **61:** 419–433

Weisse T., Scheffel U., Stadler W., Foissner W. (2013a) *Bromeliothrix metopoides*, a boom and bust ciliate (Ciliophora, Colpodea) from tank bromeliads. *Eur. J. Protistol*. **9:** 406–419

Weisse T., Scheffel U., Stadler P., Foissner W. (2013b) Functional ecology of the ciliate *Glaucomides bromelicola*, and comparison with the sympatric species *Bromeliothrix metopoides*. *J. Eukaryot. Microbiol*. **60:** 578–587

Wiackowski K., Kocerba-Soroka W. (2017) Selective predation by harpacticoid copepod on ciliates in phytotelmata: a laboratory experiment. *Hydrobiologia* **790**: 13–22

Received on 5th May, 2019; revised on 12th December, 2019; accepted on 11th February, 2020

Capítulo III

Durán-Ramírez, C. A., Mayén-Estrada, R. & Dias, R. J. P. 2020.
Checklist of ciliates (Alveolata: Ciliophora) that inhabit in bromeliads from the Neotripical Region.
Zootaxa 4895 (1): 1-36.

Zootaxa 4895 (1): 001–036
https://www.mapress.com/j/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.4895.1.1
http://zoobank.org/urn:lsid:zoobank.org:pub:435F054A-78A5-419D-8F2D-C5B608D99F53

Checklist of ciliates (Alveolata: Ciliophora) that inhabit in bromeliads from the Neotropical Region

CARLOS ALBERTO DURÁN-RAMÍREZ[1,2*], ROBERTO JÚNIO PEDROSO DIAS[3] & ROSAURA MAYÉN-ESTRADA[1,4]

[1]*Laboratorio de Protozoología, Departamento de Biología Comparada, Facultad de Ciencias, Universidad Nacional Autónoma México, Mexico City, Mexico.*
[2]*Posgrado en Ciencias Biológicas, Facultad de Ciencias, Universidad Nacional Autónoma de México.*
[3]*Laboratório de Protozoologia, Departmento de Zoologia, Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora, Juiz de Fora, Minas Gerais, Brazil.*
rjuniodias@hotmail.com; https://orcid.org/0000-0002-2404-4337
[4] *romaraf@gmail.com; https://orcid.org/0000-0002-3156-1295*
[*]*Corresponding author. carlosduran_88@ciencias.unam.mx; https://orcid.org/0000-0002-6583-0035*

Abstract

Species from almost all classes of ciliates are prone to be found inhabiting bromeliads in the Neotropics, from Mexico to Brazil, and the Antilles. Studies of ciliates recorded from bromeliads have been carried out from few bromeliad species, mainly in tropical forest. We compiled all available data of free living and sessile ciliates from bromeliads, including their geographic distribution and bromeliad identity. We provide a list of 170 ciliate species that have been recorded in 52 epiphytic and terrestrial bromeliad species, distributed in ten Neotropical countries . Most of the species belong to the Classes Oligohymenophorea, Colpodea and Spirotrichea. The largest number of ciliate species has been recorded in Brazil and Mexico. *Bromeliothrix metopoides* and *Glaucomides bromelicola* were the two species with the widest geographical distribution, 19 species have been recorded only in Mexico, 11 in the Antillean islands, and 89 only in Southamerica. Free living species prevailed over sessile species, and both represent 2% of the total ciliate species number. Sixteen ciliate species have been recorded only inhabiting in bromeliads. Although bromeliads show a high endemicity, their specificity is low in relation to ciliates.

Key words: Bromeliaceae, Endemic ciliates, Neotropics, Phytotelm, Tank bromeliads

Introduction

Ciliates are among the most diverse groups of protists that inhabit in bromeliads. Members of the family Bromeliaceae are an important component of the vascular flora of tropical forests, with more than 3,500 species distributed in the Neotropics (Givnish *et al.* 2007, Gouda & Gouda 2015). Their coalescent leaves allow the accumulation of rainwater and detritus, leading to the formation of a tank or phytotelm (Maguire 1971), which makes possible the establishment of ciliate communities (Foissner *et al*. 2003, Durán-Ramírez *et al*. 2015, Agatha *et al*. 2020).

Most of the taxonomical and ecological studies of ciliates of bromeliads have been carried out in recent years from few bromeliad species with tank morphology, and mainly in tropical forests and agroecosystems (Durán-Ramírez *et al*. 2015; Foissner *et al*. 2003). In a tropical dry-forest of Mexico, Durán-Ramírez & Mayén-Estrada (2018) reported that ciliates can also establish communities in tank-less bromeliads of genera *Bromelia* and *Tillandsia*.

The ciliate community structure in bromeliads can be categorized in two taxonomical components: a) the cosmopolitan species, which have also been recorded from soils, aquatic ecosystems and mosses, and b) species that have been recorded only in the phytotelmata of bromeliads (Foissner *et al*. 2003). According to Dunthorn *et al*. (2012), some genera of ciliates common in freshwater habitats, are absent in bromeliads like *Frontonia*, *Glaucoma*, *Trithigmostoma* and *Paramecium.*

Accepted by L. Utz: 5 Oct. 2020; published: 14 Dec. 2020

In relation to their habitat preference, ciliates can be found as free living inhabitants along the water column in tank species, between debris acumulated at the bottom of tanks or between the base of the leaves when plants retained little humidity as in the case of tank-less bromeliads, and also as epibionts of metazoa like insects and crustaceans that inhabit in the tanks (Foissner *et al*. 2003). Hyperphoresy among three frogs, ostracods and epibiont ciliates has been recorded in one bromeliad in eastern Brazil (Sabagh *et al*. 2011).

The objective of this work was to provide a checklist of ciliates that inhabit in bromeliads through a compilation of all available records in the literature, including new and unpublished records in Mexican bromeliads and their geographic distribution in the Neotropical Region, and the bromeliads identity if the case. Our results contribute to the knowledge of protist diversity in phytotelmata and distribution of ciliates in the Neotropics.

Methodology

Available records of free living and sessile ciliates species that inhabit in bromeliads from the Neotropical Region were compiled and checked. Also, some new and unpublished Mexican records were included. Their taxonomic status was verified in updated literature, and systematic was according to Lynn (2008). The checklist includes only records of ciliate species, identified with morphological approach (i. e. live observation and silver impregnation techniques), and/or with sequences data. Geographical distribution was included at country level indicating the names of localities when available. If the case, data of bromeliads identity was provided and checked in web resources of TROPICOS® from the Missouri Botanical Garden. References for each record were also provided for all the species.

We included new and unpublished records of ciliate species found in 100 individuals of bromeliads belonging to 13 species, collected during the humid season of years 2015 and 2016 in the Mexican Neotropics. Microphotographs were obtained with a Nikon Labophot-2 microscope equipped with a Nikon Digital Sight DS-L15667 camera, and Photo Microscope Olympus-Provis AX70 and Evolution MP5 megapix camera. Images were rendered by using Helicon Focus 7.6.1.

Bromeliad species refered in the literature were indicated by using the next abbreviatons: (Ab) *Aechmea bracteata* (Sw., 1788) Grisebach, 1864, (Ad) *A. distichantha* Lem., 1853, (Af) *A. phanerophlebia* Baker, 1899, (Am) *A. mexicana* Baker, 1879, (Ap) *A. paniculigera* (Sw.) Griseb., 1864, (As) *Aechmea* sp., (Bk) *Bromelia karatas* L. 1753, (Bp) *B. pinguin* L. 1753, (Cb) *Catopsis berteroniana* (Schult. & Schult. f.) Mez, 1896, (Ch) *C. oerstediana* Mez, 1896 , (Cs) *C. sessiliflora* (Ruiz & Pavón, 1802) Mez., 1896, (Gm) *Guzmania monostachia* (L.) Rusby ex Mez, 1896, (Gu) *G. musaica* (Linden & André) Mez, 1896, (Gz) *G. scherzeriana* Mez, 1896, (Gs) *Guzmania* sp., (Hi) *Hohenbergia inermis* Mez, 1913, (Hp) *H. penduliflora* (A. Rich.) Mez, 1896, (Hr) *H. proctorii* L. B. Sm., 1960, (Hn) *H. spinulosa* Mez, 1900, (Hu) *H. urbaniana* Mez, 1900, (Hs) *Hohenbergia* sp., (Ni) *Neoregelia ibitipocensis* (Leme) Leme, 1998, (No) *N. oligantha* L. B. Sm., 1955, (Nf) *Nidularium ferdinando-coburgii* Wawra, 1880, (Nm) *N. marigoi* Leme, 1991, (Pg) *Pseudalcantarea grandis* (Schltdl., 1845), (Pv) *P. viridiflora* (Beer, 1856) Pinzón & Barfuss, 2016, (Tc) *Tillandsia concolor* L. B. Sm., 1960 (Td) *T. makoyana* Baker, 1887, (Te) *T. deppeana* Steud., 1841, (Tg) *T. guatemalensis* L. B. Sm., 1949 (Ty) *T. gymnobotrya* Baker, 1887, (Th) *T. heterophylla* E. Morren, 1873, (Ti) *T. imperialis* E. Morren ex Mez., 1935, (Tb) *T. limbata* Schltdl., 1845, (Ta) *T. macrochlamys* Baker, 1888, (Tm) *T. multicaulis* Steudel., 1841, (Tp) *T. polystachia* (L., 1753) L., 1762, (To) *T. prodigiosa* Baker, 1889, (Tr) *T. rothii* Rauh, 1976, (Ts) *Tillandsia* spp., (Vb) *Vriesea bituminosa* Wawra, 1862, (Vf) *V. friburgensis* Mez, 1952, (Vg) *V. gigantea* Gaudich., 1846, (Vh) *V. heterostachys* (Baker) L. B. Sm., 1970, (Vi) *V. incurvata* Gaudich., 1843, (Vp) *V. penduliflora* L. B. Sm., 1943, (Vy) *V. platynema* Gaudich., 1843, (Vs) *V. sanguinolenta* Cogn. & Marchal, 1874, (V1) *Vriesea* sp., (Ws) *Werauhia* sp. and (Wg) *Wittrockia gigantea* (Baker) Leme, 1997.

Ciliate species that occur only in bromeliads were indicated in the checklist with superindex 1, and ciliate species identified by SSU-rDNA sequences were indicated with superindex 2. New and unpublished records of ciliate species from Mexican bromeliads were indicated with the abbreviation ps (present study).

We included a map with the geographical ubication of localities according to the Neotropical delimitation of Morrone (2017), by using the ArcGis 10.3 software.

Results

We obtained the records of 170 species of ciliates (about 2% of species of phylum Ciliophora), included in two subphyla, 10 classes, 11 subclasses, 30 orders, 64 families, and 112 genera. From these, 16 species have been reported only as inhabitants of bromeliads (endemic). Classes Oligohymenophorea, Colpodea and Spirotrichea included the larger number of species, with 38, 34 and 33 species respectively. Colpodida with 24 species was the order with the largest number of species, and family Oxytrichidae with 15 species. The genus *Colpoda* had the largest species richness (10).

The records of ciliate species belong to ten Neotropical countries (Fig. 1), being Brazil and Mexico those with the largest number of species (79 and 60 respectively). For Mexico, 22 new and unplublished records (Figs. 2-3) were included from six localities, being now the number of ciliate species in bromeliads 6.2% of the total number of ciliates reported in the country (Mayén-Estrada *et al*. 2014). For the rest of the countries included in the present study, 23 species have been recorded in both Dominican Republic and Jamaica, nine in Costa Rica, three species in Chile and Peru, five species in Colombia, 21 species in Ecuador, and 56 species in Venezuela. Ciliate species that establish communities in bromeliads, are not homogeneously distributed along the Neotropical Region. For example, 19 ciliate species have only been recorded in the portion that corresponds to Mexico, 89 only for South American countries, and only 11 in the Antilles (Dominican Republic and Jamaica).

Bromeliads included 52 species (epiphytic and terrestrial), belonging to the genera *Aechmea* Ruiz & Pavón, 1793, *Bromelia* L. 1753, *Catopsis* Grisebach, 1864, *Guzmania* Ruiz & Pavón, 1802, *Hohenbergia* Schult., 1830, *Neoregelia* B. Sm., 1934, *Nidularium* Lem., 1854, *Pseudalcantarea* (Mez) Pinzón & Barfuss, 2016, *Tillandsia* L., 1753, *Vriesea* Lindl., 1843, *Werauhia* J. R. Grant, 1995 and *Wittrockia* Lindm., 1891. According to Givnish *et al*. (2007) and Gouda & Gouda (2015), 3,543 bromeliad species inhabit the Neotropics, from which only 1.4% of the species have been included in studies about ciliate diversity.

Aechmea disthichanta in Brazil and *Tillandsia heterophylla* in Mexico, were the two bromeliad species where the largest number of ciliate species has been recorded (Buosi *et al*. 2014 a, b, 2015; Durán-Ramírez *et al*. 2015) (Fig. 4). Although most of the ciliate species were recorded in bromeliads with tank morphology, like those of genera *Aechmea* and *Guzmania*, however, Durán-Ramírez & Mayén-Estrada (2018) recorded some ciliates in tankless bromeliads of genera *Bromelia* and *Tillandsia* in a dry tropical forest in western Mexico. Other types of forests where ciliates in bromeliads have been identified are tropical forest, montane cloud forest, semideciduos tropical forest, oak and pine forest, farms, coffee plantations, and riparian vegetation (Buosi *et al*. 2014b, 2015; Durán-Ramírez *et al*. 2015; Foissner 2016).

Bromeliothrix metopoides and *Glaucomides bromelicola* were recorded in most countries (nine and seven, respectively), and *G. bromelicola* has been recorded in almost half the number of bromeliad species (27). *Bromeliophrya brasiliensis*, *B. quadristicha*, *Columnospatha bromelicola*, *Glaucomides bromelicola*, *Gonostomum bromelicola*, *Lambornella trichoglossa*, *Leptopharynx bromelicola*, *L. bromeliophilus*, *Maryna meridiana*, *Orborhabdostyla bromelicola*, *Paroxytricha quadrinucleata*, *Platyophrya bromelicola*, *Pseudovorticella bromelicola*, *Spathidium bromelicola*, *S. bromeliophilum*, and *S. wolfi* occur only in bromeliads. Figure 4 shows the relation between ciliate families recorded from the 52 bromeliad species and the countries where they have been mentioned in the literature. Bromeliads are well known to exhibit a high geographical endemicity which is shown by the colour of the lines, where none of the 52 bromeliad species were present in more than one country. By contrast, ciliate specificity to any bromeliad species is low; however, Bromeliophryidae, Colpodidae and Leptopharyngidae were the most frequent families in bromeliads. On the other hand, the high linkeage of *A. distichnatha* and some species of *Tillandsia* reflects that ciliates from only very few bromeliad species have been extensively studied.

Unlike Mexican and West Indies ciliate species, Buosi *et al*. (2014a, b, 2015) and Paz (1980) recorded in South America species from genera *Colpidium*, *Lembadion*, *Litonotus*, *Metopus* and *Paramecium*, previously considered as uncommon inhabitants of bromeliads (Dunthorn *et al*. 2012). Similarly, *Columnospatha bromelicola*, *Enchelariophrya wolfi*, *Protospathidium lepidosomatum*, *Spathidium bromelicola*, *S. bromeliophilum* and *S. wolfi* were recorded exclusively in bromeliads from Dominican Republic and Jamaica, but the endemicity of these species to those islands has not been demonstrated.

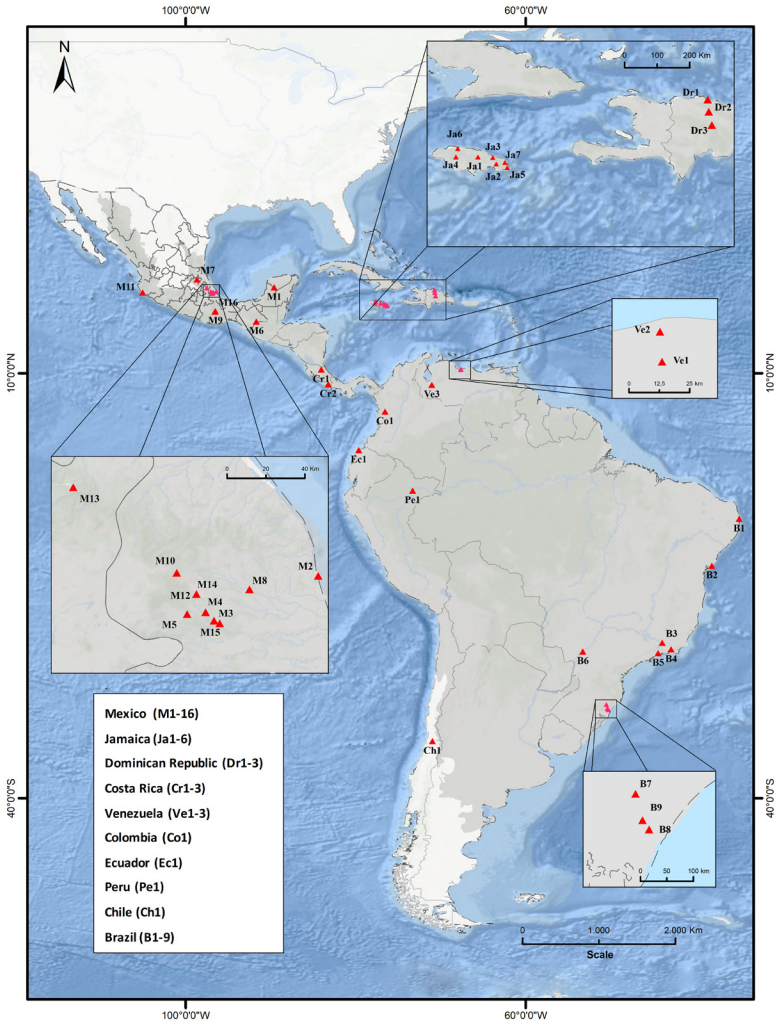


FIGURE 1. Distribution map of the localities in Neotropics refered in the literature where ciliates have been recorded in bromeliads**. Mexico**. **M1**=Biocultural Reserve Kaxil Kiuic, near Oxkutzcab, **M2**=Coastal Research Center La Mancha/CICOLMA, **M3**=Coffee plantation Arcos Vegas y Rincón de Yeguas, Tuzamapan, **M4**=Coffe plantation Virginia Armand, near Coatepec, **M5**=Coffee plantation La Onza, near Coatepec, **M6**=Dos Lagunas, near Village of Tzsicao, **M7**=El Tegolome, near the town of Tlanchinol , **M8**=Environmental Management Area Nace el Río, Descabezadero, **M9**=Ixtlán de Juárez, Oaxaca, **M10**=La Joya, Acajete, **M11**=Reserve of the Biosphere Chamela-Cuixmala, **M12**=Santuario del Bosque de Niebla, near Xalapa, **M13**=Surroundings of Reserva Azul, near the town of Cuetzalan, **M14**=Surroundings of the town of Xalapa, **M15**=Tlacuitlapa, Jalcomulco, **M16**=Village El Cerezal, near Santa Catarina Ixtepeji. **Jamaica**. **Ja1**=Mount Diablo, northwest of Spanish Town, **Ja2**=Near the Village of Ecclesdown, **Ja3**=Northern slope of the Blue Mountains, surroundings of the village of Silver Hill, **Ja4**=Parish Saint Elizabeth, near the road between the villages of Aberdeen and Quick Step, **Ja5**=Saint Thomas, at the Eastern tip of Jamaica, near the villages of Golden Grove and Rowlandsfield, **Ja6**=Surroundings of the village of Quick Step in Cockpit Country, **Ja7**=Upper Cedar Valley, southern slope of the Blue Mountains. **Dominican Republic**. **Dr1**=Botanical Garden on the Pico Isabel de Torres, 800 m high mountain on the outskirts of the town of Puerto Plata, **Dr2**=North slope of the Cordillera Central, in the surroundings of the waterfall Salto de Jimenoa, **Dr3**=Santiago de los Caballeros. **Venezuela**. **Ve1**=South margin of the Henri Pittier National Park, Biological Station Rancho Grande, **Ve2**=North border of the Henri Pittier National Park, surroundings of the village of Choroni, **Ve3**=Sierra Nevada National Park. **Costa Rica**. **Cr1**=bank of the Río Sarapiquí, Selva Verde National Park, **Cr2**=Tropic Station La Gamba. **Colombia**. **Co1**=Lloró. **Ecuador**. **Ec1**=Esmeraldas, underneath Alto Tambo. **Peru**. **Pe1**=Peru. **Chile**. **Ch1**=Chile. **Brazil**. **B1**=Nature Reserve Mata do Buraquinho in the town of João Pessoa, Paraiba, **B2**=Surroundings of the Village of Praia do Forte, about 81 km North of the town of Salvador, Bahia, **B3**=Parque Estadual do Ibitipoca, Minas Gerais, **B4**=Rio de Janeiro, **B5**= Bracuhy Port, Angra dos Reis, **B6**=Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná, **B7**=Garapia River, Rio Grande do Sul, **B8**=Maquiné River basin, Rio Grande do Sul, **B9**=Pró-Mata de São Francisco de Paula, Rio Grande do Sul.

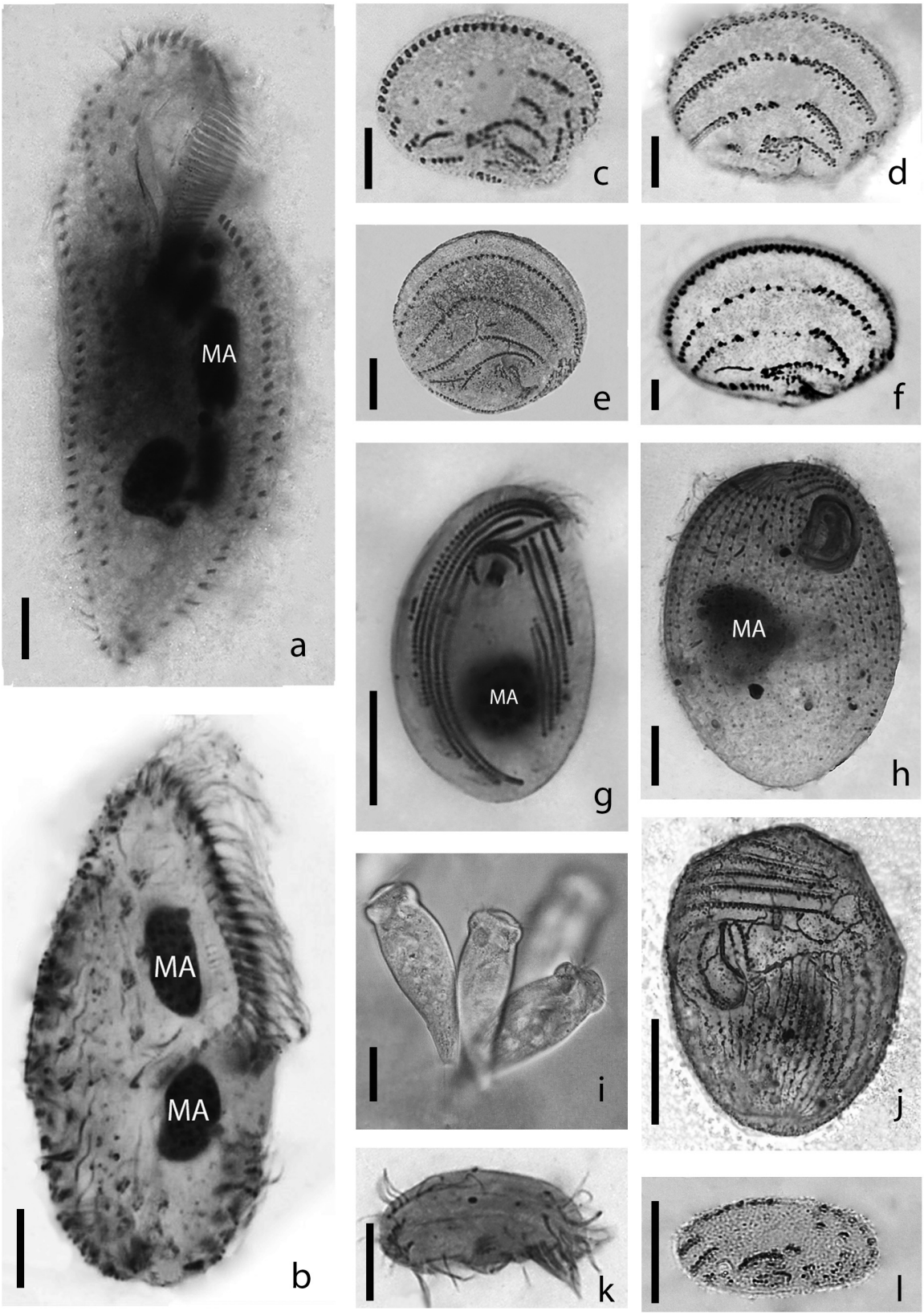


FIGURE 2. Ciliate species from Mexican bromeliads included in the present study: a. *Fragmocirrus espeletiae*, b. *Gonostomum bromelicola*, c. *Leptopharynx bromeliophilus*, d. *L. brasiliensis*, e. *L. bromelicola*, f. *L. costatus*, g. *Chilodonella uncinata*, h. *Glaucomides bromelicola*, i. *Epistylis plicatilis* (in vivo), j. *Bromeliophrya brasiliensis*, k. *Drepanomonas revoluta*, l. *D. sphagni*. MA-macronucleus; a, b, g, h, k: cells with protargol procedure (Foissner 2014); c-f, j, l. Cells impregnated with the dry silver nitrate method (Foissner 2014). Scale bars: 10µm.

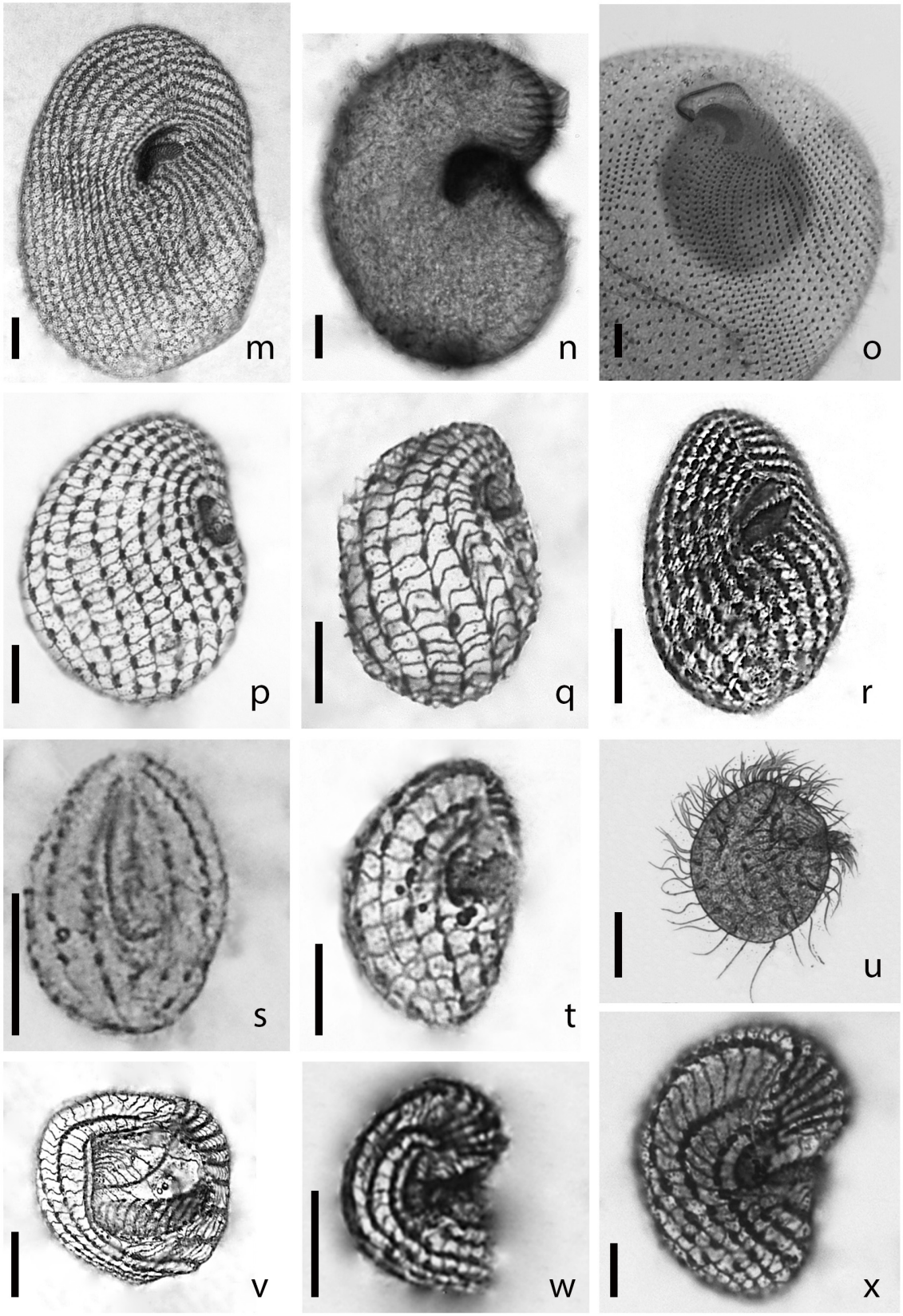
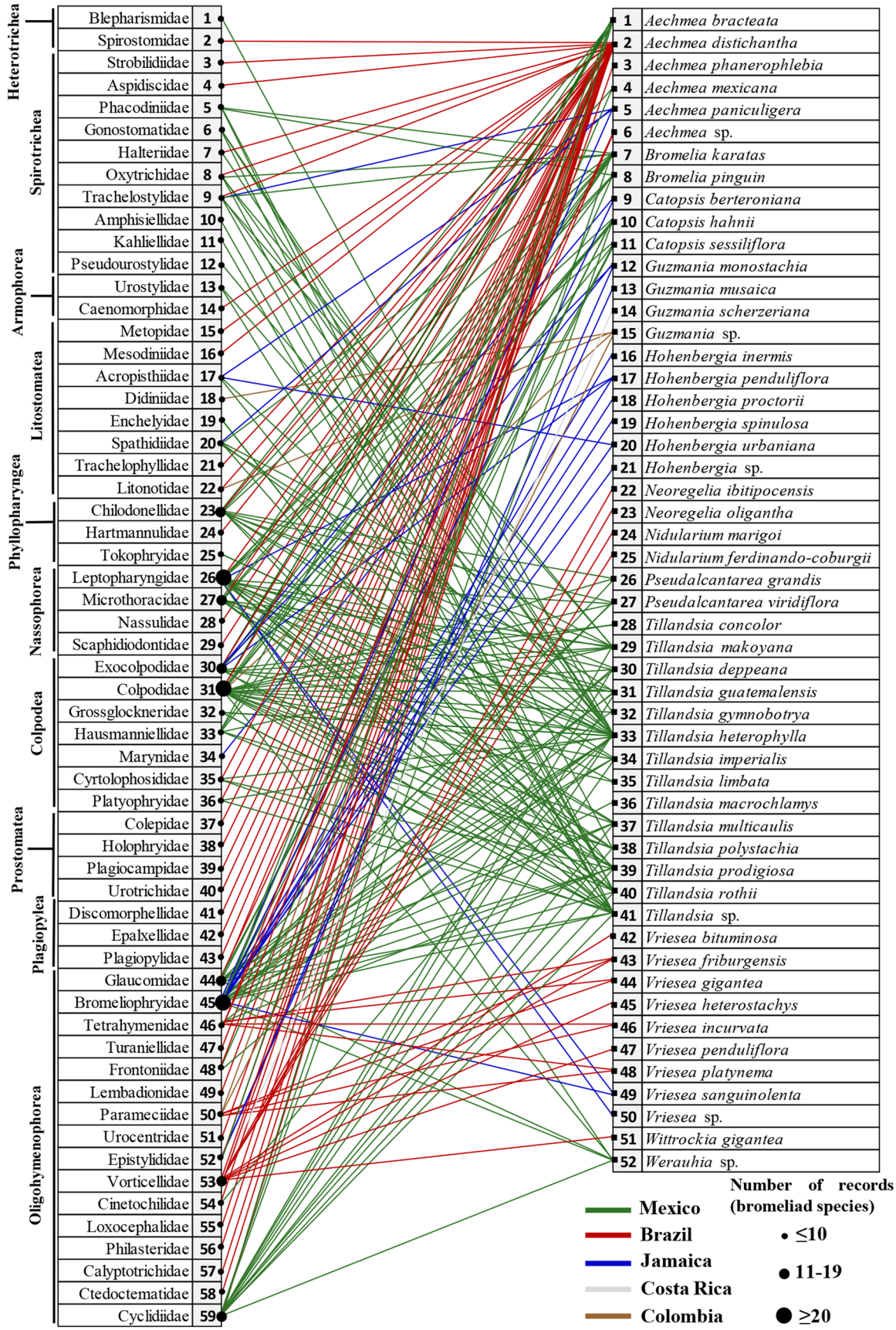


FIGURE 3. Ciliate species from Mexican bromeliads included in the present study: m. *Colpoda lucida*, n. *C. cucullus*, o. *C. cavicola*, p. *C. maupasi*, q. *Emarginatophrya aspera*, r. *C. inflata*, s. *Cyclidium glaucoma*, t. *Paracolpoda lajacola*, u. *P. steinii*, v. *Bromeliothrix metopoides* macrostome, w. microstomous theront of *B. metopoides*, x. microstomous trophont of *B. metopoides*. MA-macronucleus; m, p-x: Cells impregnated with the dry silver nitrate method (Foissner, 2014); n. Cell impregnated with nigrosine; o: Cells with silver carbonate impregnation (Fernández-Galiano 1976). Scale bars: 10µm.



†The size of the circles in the left column indicates the number of bromeliad species where ciliate families have been recorded.

FIGURE 4. Network of ciliate-bromeliad interaction. Ciliate species are represented groupped in families according to the countries where they were recorded.

Checklist

Phylum Ciliophora Doflein, 1901

Subphylum Postciliodesmatophora Gerassimova & Seravin, 1976

Class Heterotrichea Stein, 1859

Order Heterotrichida Stein, 1859

Family Blepharismidae Jankowski in Small & Lynn, 1985

Genus *Blepharisma* Perty, 1849

Blepharisma hyalinum Perty, 1849
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Blepharisma steini Kahl, 1932
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al*. 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al*. 2015), (Th).

Family Spirostomidae Stein, 1867

Genus *Spirostomum* Ehrenberg, 1834

Spirostomum ambiguum[2] (Müller, 1786) Ehrenberg, 1835
Distribution. JAMAICA: (Dunthorn *et al.* 2012).

Spirostomum minus Roux, 1901
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Subphylum Intramacronucleata Lynn, 1996

Class Spirotrichea Bütschli, 1889

Subclass Choreotrichia Small & Lynn, 1985

Order Choreotrichida Small & Lynn, 1985

Family Strobilidiidae Kahl in Doflein & Reichenow, 1929

Genus *Rimostrombidium* Jankowski, 1978

Rimostrombidium humile (Penard, 1922) Petz & Foissner, 1992
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Subclass Hypotrichia Stein, 1859

Order Euplotida Small & Lynn, 1985

Suborder Euplotina Small & Lynn, 1985

Family Aspidiscidae Ehrenberg, 1830

Genus *Aspidisca* Ehrenberg, 1830

Aspidisca cicada (Müller, 1786) Claparède & Lachmann, 1858
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Aspidisca lynceus (Müller, 1773) Ehrenberg, 1830
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al*. 2014b, 2015), (Ad).

Subclass Phacodiniidia Small & Lynn, 1985

Order Phacodiniida Small & Lynn, 1985

Family Phacodiniidae Corliss, 1979

Genus *Phacodinium* Prowazek, 1900

Phacodinium metchnikoffi (Certes, 1891) Prowazek, 1900
Distribution. MEXICO: Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Bp, Tp, Tr).

Subclass Stichotrichia Small & Lynn, 1985

Order Sporadotrichida Fauré-Fremiet, 1961

Family Gonostomatidae Small & Lynn, 1985

Genus *Cotterillia* Foissner & Stoeck, 2011

Cotterillia bromelicola[2] Foissner & Stoeck, 2011
Distribution. COSTA RICA: (Dunthorn *et al.* 2012; Foissner 2016). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); La Joya (Durán-Ramírez *et al*. 2019), (Ty); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al*. 2019), (Ts); Surroundings of the town of Xalapa (Foissner & Stoeck 2011), (Th).

Family Halteriidae Claparède & Lachmann, 1858

Genus *Halteria* Dujardin, 1841

Halteria grandinella (Müller, 1773) Dujardin, 1841

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Meseres* Schewiakoff, 1893

Meseres corlissi Petz & Foissner, 1992

Distribution. DOMINICAN REPUBLIC: (Foissner *et al.* 2003).

Family Oxytrichidae Ehrenberg, 1830

Genus *Cyrtohymena* Foissner, 1989

Cyrtohymena quadrinucleata (Dragesco & Njiné, 1971) Foissner, 1989

Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al*. 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Oxytricha* Bory de St. Vincent, 1824, in Lamouroux, Bory de St. Vincent & Deslongchamps, 1824

Oxytricha granulifera Foissner & Adam, 1983

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Oxytricha longigranulosa[2] Berger & Foissner, 1989

Distribution. ECUADOR: (Foissner *et al*. 2003). JAMAICA: (Dunthorn *et al.* 2012).

Oxytricha opisthomuscorum Foissner, Blatterer, Berger & Kohmann, 1991

Distribution. MEXICO: Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al*. 2015), (Th).

Oxytricha ottowi[2] Foissner, 1996

Distribution. BRAZIL: (Dunthorn *et al.* 2012). JAMAICA: (Dunthorn *et al*. 2012).

Oxytricha setigera Stokes, 1891

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al*. 2015), (Th).

Genus *Paroxytricha* Foissner 2016

Paroxytricha quadrinucleata[1] Foissner, 2016

Distribution. BRAZIL: (Foissner 2016). CHILE: (Foissner 2016). JAMAICA: (Foissner 2016). MEXICO: surroundings of the town of Xalapa (Foissner 2016), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Pattersoniella* Foissner, 1987

Pattersoniella vitiphila Foissner, 1987

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tr).

Genus *Rigidocortex* Berger, 1999

Rigidocortex octonucleatus (Foissner, 1988) Berger, 1999

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Rubrioxytricha* Berger, 1999

Rubrioxytricha haematoplasma (Blatterer & Foissner, 1990) Berger, 1999

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná [recorded as *Oxytricha haematoplasma*], (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Sterkiella* Foissner, Blatterer, Berger & Kohmann, 1991

Sterkiella cavicola (Kahl, 1935) Foissner, Blatterer, Berger & Kohmann, 1991

Distribution. MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al*. 2015), (Th).

Sterkiella histriomuscorum Foissner, Blatterer, Berger & Kohmann, 1991

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Stylonychia* Ehrenberg, 1830

Stylonychia mytilus (Müller, 1773) Ehrenberg, 1830

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Urosomoida* Hemberger *in* Foissner, 1982

Urosomoida agiliformis Foissner, 1982

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Urosomoida reticulata Foissner, Agatha & Berger, 2002

Distribution. COSTA RICA: (Foissner, 2003a); Rio Sarapiquí, Selva Verde National Park (Foissner *et al*. 2002).

Family Trachelostylidae Small & Lynn, 1985

Genus *Gonostomum* Sterki, 1878

Gonostomum affine (Stein, 1859) Sterki, 1878
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th, Ts). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Gonostomum bromelicola[1] Foissner 2016
Distribution. JAMAICA: (Foissner 2016), (Ap). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tr).

Gonostomum kuehnelti Foissner, 1987
Distribution. MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th).

Genus *Hemisincirra* Hemberger, 1985

Hemisincirra inquieta Hemberger, 1985
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Order Stichotrichida Fauré-Fremiet, 1961

Family Amphisiellidae Jankowski, 1979

Genus *Lamtostyla* Buitkamp, 1977

Lamtostyla australis (Blatterer & Foissner, 1988) Petz & Foissner, 1996
Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Incertae sedis **in family Amphisiellidae**

Genus *Circinella* Foissner, 1994

Circinella filiformis (Foissner, 1982) Foissner, 1994
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Family Kahliellidae Truffau, 1979

Incertae sedis **in family Kahliellidae**

Genus *Fragmocirrus* Foissner, 2000

Fragmocirrus espeletiae Foissner, 2000
Distribution. MEXICO: El Tegolome, near the town of Tlanchinol (ps), (Ts). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Order Urostylida Jankowski, 1979

Family Pseudourostylidae Jankowski, 1979

Genus *Pseudourostyla* Borror, 1972

Pseudourostyla franzi Foissner, 1987
Distribution. MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th).

Family Urostylidae Bütschli, 1889

Genus *Anteholosticha* Berger, 2003

Anteholosticha antecirrata Berger, 2006
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa [recorded as *Holosticha muscorum*] (Durán-Ramírez *et al.* 2015), (Th).

Genus *Caudiholosticha* Berger, 2003

Caudiholosticha tetracirrata (Buitkamp & Wilbert, 1974) Berger, 2003
Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Genus *Uroleptus* Ehrenberg, 1831

Uroleptus lepisma (Wenzel, 1953) Foissner, 1998
Distribution. DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th).

Class Armophorea Lynn, 2004

Order Armophorida Jankowksi, 1964

Family Caenomorphidae Poche, 1913

Genus *Caenomorpha* Perty, 1852

Caenomorpha medusala Perty, 1852
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Metopidae Kahl, 1927

Genus *Brachonella* Jankowski, 1964

Brachonella spiralis McMurrich, 1884
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Metopus* Claparède & Lachmann, 1858

Metopus minor Kahl, 1927
Distribution. ECUADOR: (Foissner *et al.* 2003)

Metopus palaeformis Kahl, 1927
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Metopus setosus Kahl, 1927
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Metopus striatus McMurrich, 1884
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Class Litostomatea Small & Lynn, 1981

Subclass Haptoria Corliss, 1974

Order Cyclotrichiida Jankowski, 1980

Family Mesodiniidae Jankowski, 1980

Genus *Mesodinium* Stein, 1863

Mesodinium pulex (Claparède & Lachmann, 1859) Stein, 1867
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Order Haptorida Corliss, 1974

Family Acropisthiidae Foissner & Foissner, 1988

Genus *Coriplites* Foissner, 1988

Coriplites proctori Oertel, Wolf, Al-Rasheid & Foissner, 2009
Distribution. JAMAICA: Dunthorn *et al.* 2012 (Ap, Hu); Parish Saint Elizabeth, near the road between the villages of Aberdeen and Quick Step (Oertel *et al.* 2009), (Ap). MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Ixtlán de Juárez (Durán-Ramírez *et al.* 2015), (To); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th).

Genus *Fuscheria* Foissner, 1983

Fuscheria terricola[2] Berger, Foissner & Adam, 1983
Distribution. BRAZIL: Rio de Janeiro (Dunthorn *et al.* 2012).

Family Didiniidae Poche, 1913

Genus *Didinium* Stein, 1859

Didinium nasutum (Müller, 1773) Stein, 1859
Distribution. COLOMBIA: Lloró (Paz 1980), (Gs).

Family Enchelyidae Ehrenberg, 1838

Genus *Enchelys* Müller, 1773

Enchelys tumida Foissner 2016
Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Family Pseudoholophryidae Berger, Foissner & Adam, 1984

Genus *Pseudoholophrya* Berger, Foissner & Adam, 1984

Pseudoholophrya terricola Berger, Foissner & Adam, 1984
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Family Spathidiidae Kahl in Doflein & Reichenow, 1929

Genus *Arcuospathidium* Foissner, 1984

Arcuospathidium cultriforme scalpriforme (Kahl, 1930) Foissner, 2003
Distribution. MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Arcuospathidium muscorum muscorum (Dragesco & Dragesco-Kernéis, 1979) Foissner, 1984
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Arcuospathidium namibiense tristicha Foissner, Agatha & Berger, 2002
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Bryophyllum* Kahl, 1931

Bryophyllum paucistriatum Foissner, Agatha & Berger, 2002
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Columnospatha* Foissner, 2016

Columnospatha bromelicola[1](Foissner *et al.* 2014) Foissner, 2016
Distribution. JAMAICA: Upper Cedar Valley, southern slope of the Blue Mountains [recorded as *Arcuospathidium bromelicola*] (Foissner 2016; Foissner *et al.* 2014).

Genus *Enchelariophrya* Foissner, 2016

Enchelariophrya wolfi Foissner, 2016
Distribution. JAMAICA: Surroundings of the village of Quick Step in Cockpit Country (Foissner 2016), (Ap).

Genus *Epispathidium* Foissner, 1984

Epispathidium ascendens (Wenzel, 1955) Foissner, 1987
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Epispathidium terricola Foissner, 1987
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Protospathidium* Dragesco & Dragesco-Kernéis in Foissner, 1984

Protospathidium lepidosomatum Foissner, Wolf, Kumar, Xu & Quintela-Alonso, 2014
Distribution. JAMAICA: Upper Cedar Valley, southern slope of the Blue Mountains (Foissner *et al.* 2014).

Genus *Spathidium* Dujardin, 1841

Spathidium bromelicola[1] Foissner, Wolf, Kumar, Xu & Quintela-Alonso, 2014
Distribution. DOMINICAN REPUBLIC: Botanical Garden on the Pico Isabel de Torres, 800 m high mountain on the outskirts of the town of Puerto Plata (Foissner *et al.* 2014).

Spathidium bromeliophilum[1] Foissner, Wolf, Kumar, Xu & Quintela-Alonso, 2014
Distribution. JAMAICA: Upper Cedar Valley, southern slope of the Blue Mountains (Foissner *et al.* 2014).

Spathidium claviforme Kahl, 1930
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th).

Spathidium procerum Kahl, 1930
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Spathidium spathula (Müller, 1773) Moody, 1912
Distribution. COLOMBIA: Lloró (Paz 1980), (Gs). MEXICO: Dos Lagunas, near village of Tzsiscao (ps); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tr).

Spathidium wolfi[1] Foissner, Wolf, Kumar, Xu & Quintela-Alonso, 2014
Distribution. JAMAICA: Mount Diablo, northwest of Spanish Town (Foissner *et al.* 2014).

Family Trachelophyllidae Kent, 1882

Genus *Enchelyodon* Claparède & Lachmann, 1859

Enchelyodon gondwanensis Foissner, 2016
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Lagynophrya* Kahl, 1927

Lagynophrya acuminata Kahl, 1953
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b), (Ad).

Order Pleurostomatida Schewiakoff, 1896

Family Litonotidae Kent, 1882

Genus *Acineria* Dujardin, 1841

Acineria uncinata Tucolesco, 1962
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Litonotus* Wrześniowski, 1870

Litonotus crystallinus (Vuxanovici, 1960) Foissner, Berger, Blatterer & Kohmann, 1995
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Litonotus fasciola Ehrenberg, 1870
Distribution. COLOMBIA: Lloró (Paz 1980), (Gs).

Litonotus varsaviensis (Wrześniowski, 1866) Wrześniowski, 1870
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Class Phyllopharyngea de Puytorac *et al.* 1974

Subclass Cyrtophoria Fauré-Frémiet in Corliss, 1956

Order Chlamydodontida Deroux, 1976

Family Chilodonellidae Deroux, 1970

Genus *Chilodonella* Strand, 1928

Chilodonella uncinata (Ehrenberg, 1838) Strand, 1928
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). ECUADOR: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coffee plantation Arcos Vegas y Rincón de Yeguas, Tuzamapan (Durán-Ramírez *et al*. 2019), (Ab, Am); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015),

(Th); (Durán-Ramírez *et al.* 2019), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); El Tegolome, near the town of Tlanchinol (ps), (Ti); Environmental Management Area Nace el Río, Descabezadero (Durán-Ramírez *et a*l. 2019), (Ab, Pg); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al*. 2019), (Pv, Te, Ts); (ps), (Te); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To).

Genus *Pseudochilodonopsis* Foissner, 1979

Pseudochilodonopsis algivora (Kahl, 1931) Foissner, 1979

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

***Incertae sedis* in family Chilodonellidae**

Genus *Odontochlamys* Certes, 1891

Odontochlamys gouraudi Certes, 1891

Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th). Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Ab, Bk, Td).

Order Dysteriida Deroux, 1976

Family Hartmannulidae Poche, 1913

Genus *Trochilioides* Kahl, 1931

Trochiloides recta (Kahl, 1928) Kahl, 1931

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Subclass Suctoria Claparède & Lachmann, 1858

Order Endogenida Collin, 1912

Family Tokophryidae Jankowski in Small & Lynn, 1985

Genus *Tokophrya* Bütschli, 1889

Tokophrya infusionum[2] (Stein, 1859) Buetschli, 1889

Distribution. MEXICO: (Dunthorn *et al.* 2012); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th).

Class Nassophorea Small & Lynn, 1981

Order Microthoracida Jankowski, 1967

Family Leptopharyngidae Kahl, 1926

Genus *Leptopharynx* Mermod, 1914

Leptopharynx australiensis Omar & Foissner, 2011
Distribution. MEXICO: Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019), (Bp).

Leptopharynx brasiliensis Foissner & Omar, 2012
Distribution. MEXICO: Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Tp, Tr); Dos Lagunas, near village of Tzsiscao (ps), (Tg).

Leptopharynx bromelicola[1,2] Foissner, Wolf, Yashchenko & Stoeck, 2011
Distribution. COSTA RICA: (Foissner *et al.* 2011). DOMINICAN REPUBLIC: (Foissner *et al.* 2011). ECUADOR: (Foissner *et al.* 2011). JAMAICA: (Dunthorn *et al.* 2012), (Hp); Northern slope of the Blue Mountains, surroundings of the village of Silver Hill (Foissner *et al.* 2011). MEXICO: (Foissner *et al.* 2011); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); El Tegolome, near the town of Tlanchinol (ps), (Ti); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Tm, Ts); (ps), (Cs, Te, Tm, Ts); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). PERU: (Foissner *et al.* 2011).

Leptopharynx bromeliophilus[1] Omar & Foissner, 2011
Distribution. JAMAICA: (Dunthorn *et al.* 2012), (Vs); near the village of Ecclesdown (Omar & Foissner 2011), (V1). MEXICO: Omar & Foissner 2011, (Th); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al*. 2019), (Tb); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near village of Tzsiscao (ps), (Ch, Tg, Ws); El Tegolome, near the town of Tlanchinol (ps), (Ti); Ixtlán de Juárez, Oaxaca (Durán-Ramírez *et al.* 2015), (To); La Joya, Acajete (Durán-Ramírez *et al*. 2019), (Ts); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Bp, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al*. 2019), (Tm, Ts); Surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs, Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To).

Leptopharynx costatus Mermod, 1914
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad); (Foissner *et al.* 2003). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: (Foissner *et al.* 2011), (Th); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near village of Tzsiscao (ps), (Tg); El Tegolome, near the town of Tlanchinol (ps), (Ti); Ixtlán de Juárez, Oaxaca (Durán-Ramírez *et al.* 2015), (To); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (ps), (Cs, Pv, Te, Tm); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs, Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To); VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Genus *Pseudomicrothorax* Mermod, 1914

Pseudomicrothorax agilis Mermod, 1914
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Microthoracidae Wrześniowski, 1870

Genus *Drepanomonas* Fresenius, 1858

Drepanomonas exigua bidentata Foissner, 1999
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Drepanomonas minuta Foissner & Omar, 2014
Distribution. MEXICO: Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tp).

Drepanomonas pauciciliata Foissner, 1987
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Drepanomonas revoluta Penard, 1922
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Tg, Tm); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Bp, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Ts); Surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th).

Drepanomonas sphagni Kahl, 1931
Distribution. MEXICO: Surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th).

Genus *Microthorax* Engelmann, 1862

Microthorax pusillus Engelmann, 1862
Distribution. ECUADOR: (Foissner *et al.* 2003). BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Stammeridium* Wenzel, 1969

Stammeridium kahli (Wenzel, 1953) Wenzel, 1969
Distribution. BRAZIL: (Foissner *et al.* 2003).

Order Nassulida Jankowski, 1967

Family Nassulidae de Fromentel, 1874

Genus *Nassulides* Foissner, Agatha & Berger, 2002

Nassulides pictus (Greeff, 1888) Foissner, Agatha & Berger, 2002
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná [recorded as *Nassula picta*] (Buosi *et al.* 2014b, 2015), (Ad).

Order Synhymeniida de Puytorac *et al.* 1978

Family Scaphidiodontidae Deroux in Corliss, 1979

Genus *Chilodontopsis* Blochmann, 1895

Chilodontopsis depressa (Perty, 1852) Blochmann, 1895
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Class Colpodea Small & Lynn, 1981

Order Bryometopida Foissner, 1985

Family Bryometopidae Jankowski, 1980

Genus *Bryometopus* Kahl, 1932

Bryometopus triquetus Foissner, 1993
Distribution. BRAZIL: (Foissner *et al.* 2003).

Family Kreyellidae Foissner, 1979

Genus *Microdiaphanosoma* Wenzel, 1953

Microdiaphanosoma arcuatum (Grandori & Grandori, 1934) Wenzel, 1953
Distribution. ECUADOR: (Foissner *et al.* 2003).

Order Bryophryida de Puytorac, Perez-Paniagua & Perez-Silva, 1979

Family Bryophryidae de Puytorac, Perez-Paniagua & Perez-Silva, 1979

Genus *Notoxoma* Foissner, 1993

Notoxoma parabryophryides Foissner, 1993
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Order Colpodida de Puytorac *et al.* 1974

Family Colpodidae Bory de St. Vincent, 1826

Genus *Bresslaua* Kahl, 1931

Bresslaua insidiatrix Claff, Dewey & Kidder, 1941
Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Bresslaua vorax Kahl, 1931
Distribution. COLOMBIA: (Paz 1980), (Gs). BRAZIL: (Foissner *et al.* 2003).

Genus *Colpoda* Müller, 1773

Colpoda cavicola Kahl, 1935
Distribution. MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab).

Colpoda cucullus (Müller, 1773) Gmelin, 1790
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). ECUADOR: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019), (Bp, Tc); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Tb, Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Cs, Ch, Tg, Tm, Ts); El Tegolome, near the town of Tlanchinol (ps), (Ti, Ts); Environmental Management Area Nace el Río, Descabezadero (Durán-Ramírez *et a*l. 2019), (Ab); La Joya, Acajete (Durán-Ramírez *et al*. 2019), (Ty); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Te, Ts); (ps), (Cs, Pv, Te); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs, Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Colpoda edaphoni Foissner, 1980
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Colpoda elliotti Bradbury & Outka, 1967
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Colpoda henneguyi Fabré-Domergue, 1889
Distribution. MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Ixtlán de Juárez (Durán-Ramírez *et al.* 2015), (To); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Colpoda inflata (Stokes, 1884) Kahl, 1931
Distribution. BRAZIL: (Foissner *et al.* 2003); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts); Sierra Nevada National Park (Foissner 2016).

Colpoda lucida Greeff, 1888
Distribution. BRAZIL: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Tg);

Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To).

Colpoda magna (Gruber, 1879) Lynn, 1978

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Colpoda maupasi Enriques, 1908

Distribution. DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019), (Bp, Tc); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Tg, Tm, Ws); El Tegolome, near the town of Tlanchinol (ps), (Ti, Tm, Ts); Environmental Management Area Nace el Río, Descabezadero (Durán-Ramírez *et a*l. 2019) , (Ab, Pg); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Ab, Bk, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Ts); (ps), (Cs, Te); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs, Th); Tlacuitlapa, Jalcomulco (Durán-Ramírez *et al*. 2019), (Ab, Pg); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Colpoda praestans Penard, 1922

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Incertae sedis in Family Colpodidae

Genus *Paracolpoda* Lynn, 1987

Paracolpoda lajacola Foissner 2016

Distribution. MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Dos Lagunas, near Village of Tzsiscao (ps), (Tg); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To).

Paracolpoda steinii (Maupas, 1883) Lynn, 1974

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná [recorded as *Colpoda steinii*] (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: [recorded as *Colpoda steinii*] (Foissner *et al.* 2003). ECUADOR: [recorded as *Colpoda steinii*] (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019), (Bp); Dos Lagunas, near Village of Tzsiscao (ps), (Ch, Tg, Ws); Coffee plantation La Onza, near Coatepec [recorded as *Colpoda steinii*] (Durán-Ramírez *et al.* 2015), (Th); El Tegolome, near the town of Tlanchinol (ps), (Ti, Tm, Ts); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Ab, Bk, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa [recorded as *Colpoda steinii*] (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Ts); (ps), (Tm); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Family Exocolpodidae Foissner, Agatha & Berger, 2002

Genus *Bromeliothrix* Foissner, 2010

Bromeliothrix metopoides[2] Foissner, 2010

Distribution. BRAZIL: (Dunthorn *et al.* 2012; Weisse *et al.* 2013a, b); Nature Reserve Mata do Buraquinho in the town of João Pessoa, Paraiba (Foissner 2010); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). CHILE: (Foissner 2010). COSTA RICA: (Foissner 2010). DOMINICAN REPUBLIC: (Foissner 2010). ECUADOR: (Foissner 2010). JAMAICA: (Dunthorn *et al.* 2012), (Cb, Gm, Hp); (Foissner 2010). MEXICO: (Foissner 2010); Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019) (Tc); Coffee plantation Arcos Vegas y Rincón de Yeguas, Tuzamapan (Durán-Ramírez *et al*. 2019) (Ab); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Ch, Tg); Environmental Management Area Nace el Río, Descabezadero (Durán-Ramírez *et a*l. 2019) (Ab); Ixtlán de Juárez (Durán-Ramírez *et al.* 2015), (To); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Ts); (ps), (Te, Ts); Surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To). PERU: (Foissner 2010). VENEZUELA: (Foissner 2010).

Family Grossglockneridae Foissner, 1980

Genus *Grossglockneria* Foissner, 1980

Grossglockneria hyalina Foissner, 1985

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016)

Genus *Mykophagophrys* Foissner, 1995

Mykophagophrys terricola (Foissner, 1985) Foissner, 1995

Distribution. MEXICO: Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Genus *Nivaliella* Foissner, 1980

Nivaliella plana Foissner, 1980

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Genus *Pseudoplatyophrya* Foissner, 1980

Pseudoplatyophrya nana (Kahl, 1926) Foissner, 1980

Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Pseudoplatyophrya saltans Foissner, 1988

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Family Hausmanniellidae Foissner, 1987

Genus *Bresslauides* Blatterer & Foissner, 1988

Bresslauides terricola (Foissner, 1987) Foissner, 1993
Distribution. MEXICO: Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tr).

Genus *Emarginatophrya* Foissner 2016

Emarginatiophrya aspera (Kahl, 1926) Foissner 2016
Distribution. MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Dos Lagunas, near Village of Tzsiscao (ps), (Tg); Reserve of the Biosphere Chamela-Cuixmala [recorded as *Colpoda aspera*] (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tp, Tr); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs).

Genus *Hausmanniella* Foissner, 1984

Hausmanniella patella (Kahl, 1931) Foissner, 1984
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Family Marynidae Poche, 1913

Genus *Maryna* Gruber, 1879

Maryna meridiana[1] Foissner 2016
Distribution. COSTA RICA: (Foissner 2016). JAMAICA: (Foissner 2016), (Gm).

Order Cyrtolophosidida Foissner, 1978

Family Cyrtolophosididae Stokes, 1888

Genus *Cyrtolophosis* Stokes, 1885

Cyrtolophosis minor[2] Vuxanovici, 1963
Distribution. JAMAICA: (Dunthorn *et al.* 2012).

Cyrtolophosis mucicola Stokes, 1885
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad); (Foissner *et al.* 2003). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Genus *Pseudocyrtolophosis* Foissner, 1980

Pseudocyrtolophosis alpestris Foissner, 1980

Distribution. BRAZIL: (Foissner *et al.* 2003). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: Ixtlán de Juárez (Durán-Ramírez *et al.* 2015), (To); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016); North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Incertae sedis **in family Cyrtolophosididae**

Genus *Plesiocaryon* Foissner, Agatha, & Berger, 2002

Plesiocaryon elongatum (Schewiakoff, 1892) Foissner, Agatha & Berger, 2002

Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Family Platyophryidae de Puytorac, Perez-Paniagua & Perez-Silva, 1979

Genus *Platyophrya* Kahl, 1926

Platyophrya bromelicola[1,2] Foissner, 2008

Distribution. BRAZIL: (Dunthorn *et al.* 2012; Foissner 2016); Rio de Janeiro (Foissner 2016). JAMAICA: (Foissner 2016); Saint Thomas, at the eastern tip of Jamaica, near the villages of Golden Grove and Rowlandsfield (Foissner & Wolf 2009). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th).

Platyophrya macrostoma Foissner, 1980

Distribution. VENEZUELA: North border of the Henri Pittier National Park, surroundings of the village of Choroni (Foissner 2016), (Ts).

Platyophyra vorax Kahl, 1926

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003).

Class Prostomatea Schewiakoff, 1896

Order Prorodontida Corliss, 1974

Family Colepidae Ehrenberg, 1838

Genus *Coleps* Nitzsch, 1827

Coleps hirtus (Müller, 1786) Nitzsch, 1827

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Holophryidae Perty, 1852

Genus *Holophrya* Ehrenberg, 1831

Holophrya teres (Ehrenberg, 1833) Foissner, Berger & Kohmann, 1994
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Plagiocampidae Kahl, 1926

Genus *Plagiocampa* Schewiakoff, 1893

Plagiocampa rouxi Kahl, 1926
Distribution. BRAZIL: (Foissner *et al.* 2003); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Urotrichidae Small & Lynn, 1985

Genus *Bursellopsis* Corliss, 1960

Bursellopsis spumosa (Schmidt, 1920) Corliss, 1960
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Urotricha* Claparède & Lachmann, 1859

Urotricha farcta Claparède & Lachmann, 1859
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Class Plagiopylea Small & Lynn, 1985

Order Odontostomatida Sawaya, 1940

Family Discomorphellidae Corliss, 1960

Genus *Discomorphella* Corliss, 1960

Discomorphella pectinata (Levander, 1894) Corliss, 1960
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Epalxellidae Corliss, 1960

Genus *Saprodinium* Lauterborn, 1908

Saprodinium dentatum (Lauterborn, 1901) Lauterborn, 1908
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Order Plagiopylida Jankowski, 1978

Family Plagiopylidae Schewiakoff, 1896

Genus *Plagiopyla* Stein, 1860

Plagiopyla nasuta Stein, 1860

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Class Oligohymenophorea de Puytorac *et al.* 1974

Subclass Hymenostomatia Delàge & Hérouard, 1896

Order Tetrahymenida Fauré-Fremiet in Corliss, 1956

Family Glaucomidae Corliss, 1971

Genus *Bromeliophrya* Foissner, 2003

Bromeliophrya brasiliensis[1,2] Foissner, 2003

Distribution. BRAZIL: (Dunthorn *et al.* 2012; Foissner *et al.* 2003); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad); Surroundings of the Village of Praia do Forte, about 81 km North of the town of Salvador, Bahia (Foissner 2003a), (As). ECUADOR: (Foissner *et al.* 2003). JAMAICA: (Dunthorn *et al.* 2012). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2019), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Ch, Tg, Tm, Ws); El Tegolome, near the town of Tlanchinol (ps), (Ti); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al*. 2019), (Te, Ts); (ps), (Cs, Pv, Te); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To); (Durán-Ramírez *et al.* 2016).

Bromeliophrya quadristicha[1] Foissner & Stoeck, 2013

Distribution. DOMINICAN REPUBLIC: Botanical Garden on the Pico Isabel de Torres, 800 m high mountain on the outskirts of the town of Puerto Plata (Foissner & Stoeck 2013). JAMAICA: Northern slope of the Blue Mountains, surroundings of the village of Silver Hill (Foissner & Stoeck 2013).

Genus *Glaucoma* Ehrenberg, 1830

Glaucoma reniforme Schewiakoff, 1892

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Glaucoma scintillans Ehrenberg, 1830

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Bromeliophryidae Foissner, 2003

Genus *Glaucomides* Foissner, 2013

Glaucomides bromelicola[1,2] Foissner, 2013

Distribution. CHILE: (Foissner 2013). DOMINICAN REPUBLIC: (Dunthorn *et al.* 2012; Weisse *et al.* 2013a);

Botanical Garden on the Pico Isabel de Torres, 800 m high mountain on the outskirts of the town of Puerto Plata (Foissner 2013). ECUADOR: (Foissner 2013). JAMAICA: (Foissner 2013); (Dunthorn *et al.* 2012), (Ap, Cb, Gm, Hi, Hp, Hr, Hn, Hs, Hu, Ts, Vs). MEXICO: Coffee plantation Arcos Vegas and Rincón de Yeguas, Tuzamapan (Durán-Ramírez *et al*. 2019), (Ab, Am); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al*. 2019), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Ch, Tg, Tm, Ws); El Tegolome, near the town of Tlanchinol (ps), (Ti, Tm, Ts); La Joya, Acajete (Durán-Ramírez *et al*. 2019), (Ta, Ts, Ty); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Durán-Ramírez *et al.* 2019), (Pv, Te, Tm, Ts); (ps), (Cs, Te, Tm, Ts); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Cs, Th); Tlacuitlapa, Jalcomulco (Durán-Ramírez *et al*. 2019), (Ab, Pg); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To); (Foissner 2013). PERU: (Foissner 2013). VENEZUELA: (Foissner 2013).

Family Tetrahymenidae Corliss, 1952

Genus *Lambornella* Keilin, 1921

Lambornella trichoglossa[1,2] Foissner, 2003

Distribution. BRAZIL: (Dunthorn *et al.* 2012; Foissner *et al.* 2003); Garapia River, Rio Grande do Sul (Malfatti 2019), (Vi); Maquiné River basin, Rio Grande do Sul (Malfatti 2019), (Vg); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad); Pró-Mata de São Francisco de Paula, Rio Grande do Sul (Malfatti 2019), (Vf, Vy); Surroundings of the Village of Praia do Forte, about 81 km North of the town of Salvador, Bahia (Foissner 2003b), (As);. ECUADOR: (Foissner *et al.* 2003). DOMINICAN REPUBLIC: (Foissner *et al.* 2003); North slope of the Cordillera Central, in the surroundings of the waterfall Salto de Jimenoa (Foissner 2003b); Santiago de los Caballeros (Foissner 2003b). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Ixtlán de Juárez (Durán-Ramírez *et al.* 2015), (To).

Genus *Tetrahymena* Furgason, 1940

Tetrahymena rostrata (Kahl, 1926) Corliss, 1952

Distribution. BRAZIL: (Foissner *et al.* 2003). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th).

Family Turaniellidae Didier, 1971

Genus *Colpidium* Stein, 1860

Colpidium colpoda (Losana, 1829) Stein, 1860

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Colpidium kleini Foissner, 1969

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Dexiostoma* Jankowski, 1967

Dexiostoma campylum (Stokes, 1886) Jankowski, 1967

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Subclass Peniculia Fauré-Fremiet in Corliss, 1956

Order Peniculida Fauré-Fremiet in Corliss, 1956

Family Frontoniidae Kahl, 1926

Genus *Frontonia* Ehrenberg, 1838

Frontonia depressa (Stokes, 1886) Kahl, 1931

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Frontonia leucas (Ehrenberg, 1833) Ehrenberg, 1838

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Frontonia pusilla Fan *et al*. 2013

Distribution. MEXICO: Coastal Research Center CICOLMA (Durán-Ramírez *et al*. 2019), (Bp).

Family Lembadionidae Jankowski in Corliss, 1979

Genus *Lembadion* Pery, 1849

Lembadion bullinum (Müller, 1786) Perty, 1849

Distribution. BRAZIL: Bracuhy Port, Angra dos Reis (Esteves & Silva-Neto 1996); Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Lembadion lucens (Maskell, 1887) Kahl, 1931

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Parameciidae Dujardin, 1840

Genus *Paramecium* Müller, 1773

Paramecium caudatum Ehrenberg, 1833

Distribution. BRAZIL: Garapia River, Rio Grande do Sul (Malfatti 2019), (Vi); Maquiné River basin, Rio Grande do Sul (Malfatti 2019), (Vg); Pró-Mata, in São Francisco de Paula, Rio Grande do Sul (Malfatti 2019), (Vf, Vy). COLOMBIA: (Paz 1980), (Gs).

Paramecium multimicronucleatum Powers & Mitchell, 1910

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014a, b, 2015), (Ad).

Paramecium putrinum Claparède & Lachmann, 1859

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Order Urocentrida Jankowski, 1980

Family Urocentridae Claparède & Lachmann, 1858

Genus *Urocentrum* Nitzsch, 1827

Urocentrum turbo (Müller, 1786) Nitzsch, 1827
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Subclass Peritrichia Stein, 1859

Order Sessilida Kahl, 1933

Family Epistylididae Kahl, 1933

Genus *Campanella* Goldfuss, 1820

Campanella umbellaria (Linnaeus, 1758) Goldfuss, 1820
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Epistylis* Ehrenberg, 1830

Epistylis plicatilis Ehrenberg, 1831
Distribution. MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab).

Genus *Orborhabdostyla* Foissner, Blake, Wolf, Breiner & Stoeck, 2009

Orborhabdostyla bromelicola[1,2] Foissner, Blake, Wolf, Breiner & Stoeck, 2009
Distribution. ECUADOR: Esmeraldas, underneath Alto Tambo (Foissner *et al.* 2009), (Gm). JAMAICA: (Dunthorn *et al.* 2012), (Gu).

Family Vorticellidae Ehrenberg, 1838

Genus *Pseudovorticella* Foissner & Schiffmann, 1975

Pseudovorticella bromelicola[1] Foissner, Blake, Wolf, Breiner & Stoeck, 2009
Distribution. BRAZIL: Parque Estadual do Ibitipoca, Minas Gerais (Costa-Muniz 2019), (Af, Nf, Ni, Nm, No, Vb, Vf, Vh, Vp, Wg). COSTA RICA: Tropic station La Gamba (Foissner *et al.* 2009), (Gz).

Genus *Vorticella* Linnaeus, 1767

Vorticella convallaria[2] Linnaeus, 1758
Distribution. JAMAICA: (Dunthorn *et al.* 2012).

Vorticella gracilis[2] Dujardin, 1841
Distribution. COSTA RICA: (Dunthorn *et al.* 2012; Foissner *et al.* 2009). JAMAICA: (Dunthorn *et al.* 2012).

Genus *Vorticellides* Foissner, Blake, Wolf, Breiner & Stoeck, 2009

Vorticellides aquadulcis[2] (Stokes, 1887) Foissner, Blake, Wolf, Brenier & Stoeck, 2009

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná [recorded as *Vorticella aquadulcis*] (Buosi *et al.* 2014b, 2015), (Ad). COSTA RICA: (Foissner *et al.* 2009). MEXICO: Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (Dunthorn *et al.* 2012).

Vorticellides astyliformis[2] (Foissner, 1981) Foissner, Blake, Wolf, Brenier & Stoeck, 2009

Distribution. COSTA RICA: (Dunthorn *et al.* 2012; Foissner *et al.* 2009). VENEZUELA: South margin of the Henri Pittier National Park Biological Station Rancho Grande [recorded as *Vorticella astyliformis*] (Foissner 2016).

Subclass Scuticociliatia Small, 1967

Order Philasterida Small, 1967

Family Cinetochilidae Perty, 1852

Genus *Cinetochilum* Perty, 1849

Cinetochilum margaritaceum (Ehrenberg, 1830) Perty, 1852

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003).

Genus *Sathrophilus* Corliss, 1960

Sathrophilus muscorum (Kahl, 1931) Corliss, 1960

Distribution. BRAZIL: (Foissner *et al.* 2003). MEXICO: Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th). VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Family Loxocephalidae Jankowski, 1964

Genus *Dexiotricha* Stokes, 1885

Dexiotricha granulosa (Kent, 1881) Foissner, Berger & Kohmann, 1994

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). ECUADOR: (Foissner *et al.* 2003).

Family Philasteridae Kahl, 1931

Genus *Kahlilembus* Grolière & Couteaux, 1984

Kahlilembus attenuatus (Smith, 1897) Foissner, Berger & Kohmann, 1994

Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Genus *Philasterides* Kahl, 1931

Philasterides armatus (Kahl, 1926) Kahl, 1931
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Uronematidae Thompson, 1964

Genus *Homalogastra* Kahl, 1926

Homalogastra setosa Kahl, 1926
Distribution. VENEZUELA: South margin of the Henri Pittier National Park, Biological Station Rancho Grande (Foissner 2016).

Order Pleuronematida Fauré-Fremiet in Corliss, 1956

Family Calyptotrichidae Small & Lynn, 1985

Genus *Calyptotricha* Phillips, 1882

Calyptotricha lanuginosa (Penard, 1922) Wilbert & Foissner, 1980
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Ctedoctematidae Small & Lynn, 1985

Genus *Ctedoctema* Stokes, 1884

Ctedoctema acanthocryptum Stokes, 1884
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Family Cyclidiidae Ehrenberg, 1838

Genus *Cyclidium* Müller, 1773

Cyclidium glaucoma Müller, 1773
Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad). DOMINICAN REPUBLIC: (Foissner *et al.* 2003). ECUADOR: (Foissner *et al.* 2003). MEXICO: Biocultural Reserve Kaxil Kiuic, near Oxkutzcab (ps), (Ab); Coffee plantation La Onza, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec (Durán-Ramírez *et al.* 2015), (Th); Dos Lagunas, near Village of Tzsiscao (ps), (Ch, Tg, Tm, Ws); El Tegolome, near the town of Tlanchinol (ps), (Ti, Tm, Ts); Reserve of the Biosphere Chamela-Cuixmala (Durán-Ramírez & Mayén-Estrada 2018), (Bk, Td, Tp, Tr); Santuario del Bosque de Niebla, near Xalapa (Durán-Ramírez *et al.* 2015), (Th); (ps), (Te); surroundings of Reserva Azul, near the town of Cuetzalan (ps), (Th); Village El Cerezal, near Santa Catarina Ixtepeji (ps), (To).

Cyclidium heptatrichum Schewiakoff, 1893

Distribution. BRAZIL: Paraná River between the Nupelia's Field Station and the district of Porto São José, São Pedro do Paraná (Buosi *et al.* 2014b, 2015), (Ad).

Genus *Protocyclidium* Alekperov, 1993

Protocyclidium muscicola (Kahl, 1931) Foissner, Agatha & Berger, 2002

Distribution. BRAZIL: [recorded as *Cyclidium muscicola*] (Foissner *et al.* 2003). DOMINICAN REPUBLIC: [recorded as *Cyclidium muscicola*] (Foissner *et al.* 2003). ECUADOR: [recorded as *Cyclidium muscicola*] (Foissner *et al.* 2003). MEXICO: Coffee plantation La Onza, near Coatepec [recorded as *Cyclidium muscicola*] (Durán-Ramírez *et al.* 2015), (Th); Coffee plantation Virginia Armand, near Coatepec [recorded as *Cyclidium muscicola*] (Durán-Ramírez *et al.* 2015), (Th).

Acknowledgements

To Posgrado en Ciencias Biológicas, UNAM and National Council of Science and Technology (CONACYT) for the grant number 224627 to CADR; to Biól. M. Reyes-Santos, Facultad de Ciencias, UNAM for her technical assistance; to family Medina, the owners of the Forest Area El Tegolome, and Mr. James Callaghan for his permission to collect the samples in the Biocultural Reserve Kaxil Kiuic; to Mag. A. Martínez-Mena, Laboratory of Microcine, Facultad de Ciencias, UNAM and Biól. V. M. Romero-Niembro for the technical assistance with microphotographs; to Conselho Nacional de Desenvolvimento Científico e Tecnólogico (CNPq) providing research grants to RJP Dias (Bolsa de Produtividade em Pesquisa 2019-2021).

References

Agatha, S., Utz, L.R.P., Zufall, R.A. & Warren, A. (2020) Symposium on Ciliates in memory of Denis Lynn. *European Journal of Protistology,* 2020, 125694.
https://doi.org/10.1016/j.ejop.2020.125694

Buosi, P.R.B., Cabral, A.F., Simão, T.L.L., Utz, L.R.P. & Velho, L.F.M. (2014a) Multiple lines of evidence shed light on the occurrence of *Paramecium* (Ciliophora, Oligohymenophorea) in bromeliad tank water. *Journal of Eukaryotic Microbiology*, 61, 2–10.
https://doi.org/10.1111/jeu.12071

Buosi, P.R.B., Utz, L.R.P., de Meira, B.R., Segóvia da Silva, B.T., Lansac-Tôha, F.M., Lansac-Tôha, F.A.L. & Velho, L.F.M. (2014b) Rainfall influence on species composition of the ciliate community inhabiting bromeliad phytotelmata. *Zoological Studies*, 53, 1–12.
https://doi.org/10.1186/s40555-014-0032-4

Buosi, P.R.B., Cabral, A.F., Utz, L.R.P., Vieira, L.C.G. & Velho, L.F.M. (2015) Effects of seasonality and dispersal on the ciliate community inhabiting bromeliad phytotelmata in riparian vegetation of a large tropical river. *Journal of Eukaryotic Microbiology*, 62 (6), 737–749.
https://doi.org/10.1111/jeu.12232

Costa-Muniz, S.J. (2019) *Ciliados endémicos (Alveolata, Ciliophora) que habitam fitotelmata em bromelias do Parque Estadual do Ibitipoca, Minas Gerais, Brasil: diversidade, especificidade e notas sobre conservação*. Master Thesis, Universidade Federal de Juiz de Fora, Minas Gerais. 66p.

Dunthorn, M., Stoeck, T., Wolf, K., Breiner, H.W. & Foissner, W. (2012) Diversity and endemism of ciliates inhabiting Neotropical phytotelmata. *Systematics and Biodiversity*, 10 (2), 195–205.
https://doi.org/10.1080/14772000.2012.685195

Durán-Ramírez, C.A. & Mayén-Estrada, R. (2018) Ciliate species from tank-less bromeliads in a dry tropical forest and their geographical distribution in the Neotropics. *Zootaxa*, 4497 (2), 241–257.
https://doi.org/10.11646/zootaxa.4497.2.5

Durán-Ramírez, C.A., Mayén-Estrada, R. & Romero-Niembro, V.M. (2019) Ciliate community structure in bromeliads of different types of vegetation in eastern Mexico. *Acta Protozoologica*, 58 (3), 155–165.
https://doi.org/10.4467/16890027AP.19.015.11916

Durán-Ramírez, C.A., García-Franco, J.G., Foissner, W. & Mayén-Estrada, R. (2015) Free living ciliates from epiphytic tank bromeliads in Mexico. *European Journal of Protistology*, 51, 15–33.
https://doi.org/10.1016/j.ejop.2014.09.002

Durán-Ramírez, C.A., Mayén-Estrada, R. & Ciros-Pérez, J. (2016) First record of *Bromeliophrya brasiliensis* Foissner, 2003 (Ciliophora: Glaucomidae) from tank bromeliads in Mexico with some notes on its distribution and ecology. *Protistology*, 10 (2), 16.

Esteves, C.B. & da Silva Neto, I.D. (1996) Study of Hymenostomatida ciliates found in water tanks of Bromeliaceae from Bracuhy Port, Angra dos Reis, Rio de Janeiro. *Memórias do Instituto Oswaldo Cruz*, 91 (Supplement), 63. [abstract]

Fernández-Galiano, D. (1976) Silver impregnation of ciliated protozoa: procedure yielding good results with the pyridinated silver carbonate method. *Transactions of the American Microscopy Society*, 95, 557–560.
https://doi.org/10.2307/3225377

Foissner, W. (2003a) Morphology and ontogenesis of *Bromeliophrya brasiliensis* gen. n., sp. n., a new ciliate (Protozoa: Ciliophora) from Brazilian tank bromeliads (Bromeliaceae). *Acta Protozoologica*, 42, 55–70.

Foissner, W. (2003b) Morphology and ontogenesis of *Lambornella trichoglossa* nov. spec., a new tetrahymenid ciliate (Protozoa: Ciliophora) from Brazilian tank bromeliads (Bromeliaceae). *European Journal of Protistology*, 39, 63–82.
https://doi.org/10.1078/0932-4739-00887

Foissner, W. (2010) Life cycle, morphology, ontogenesis, and phylogeny of *Bromeliothrix metopoides* nov. gen., nov. spec., a peculiar ciliate (Protista, Colpodea) from tank bromeliads (Bromeliaceae). *Acta Protozoologica*, 49 (3), 159–193.

Foissner, W. (2013) Description of *Glaucomides bromelicola* n. gen., n. sp. (Ciliophora, Tetrahymenida), a macrostome-forming inhabitant of bromeliads (Bromeliaceae), including redescriptions of *Glaucoma scintillans* and *G. reniformis*. *Journal of Eukaryotic Microbiology*, 60, 137–157.
https://doi.org/10.1111/jeu.12016

Foissner, W. (2014) An update of 'basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa'. *International Journal of Systematic and Evolutionary Microbiology*, 64, 271–292.
https://doi.org/10.1099/ijs.0.057893-0

Foissner, W. (2016) Terrestrial and semiterrestrial ciliates (Protozoa, Ciliophora) from Venezuela and Galapagos. *Denisia*, 35, 1–912.

Foissner, W. & Wolf, K. (2009) Morphology and ontogenesis of *Platyophrya bromelicola* nov. spec., a new macrostome-forming colpodid (Protists, Ciliophora) from tank bromeliads of Jamaica. *European Journal of Protistology*, 45, 87–97.
https://doi.org/10.1016/j.ejop.2008.07.003

Foissner, W. & Stoeck, T. (2011) *Cotterillia bromelicola* nov. gen., nov. spec., a gonostomatid ciliate (Ciliophora, Hypotricha) from tank bromeliads (Bromeliaceae) with *de novo* originating dorsal kineties. *European Journal of Protistology*, 47, 29–50.
https://doi.org/10.1016/j.ejop.2010.08.003

Foissner, W. & Stoeck, T. (2013) Morphology of *Bromeliophrya quadristicha* n. spec., an inhabitant of tank bromeliads (Bromeliaceae), and phylogeny of the Bromeliophryidae (Ciliophora, Tetrahymenida). *Journal of Eukaryotic Microbiology*, 60, 223–234.
https://doi.org/10.1111/jeu.12020

Foissner, W., Agatha, S. & Berger, H. (2002) Soil ciliates (Protozoa, Ciliophora) from Namibia (Southwest Africa), with emphasis on two contrasting environments, the Etosha region and the Namib Desert. Part I. *Denisia*, 5, 1–1063.

Foissner, W., Strüder-Kypke, M., van der Staay, G., Moon-van der Staay, S. & Hackstein, J. (2003) Endemic ciliates (Protozoa, Ciliophora) from tank bromeliads (Bromeliaceae): a combined morphological, molecular, and ecological study. *European Journal of Protistology*, 39, 365–372.
https://doi.org/10.1078/0932-4739-00005

Foissner, W., Blake, N., Wolf, K., Breiner, H.W. & Stoeck, T. (2009) Morphological and molecular characterization of some peritrichs (Ciliophora: Peritrichida) from tank bromeliads, including two new genera: *Orborhabdostyla* and *Vorticellides*. *Acta Protozoologica*, 48 (4), 291–319.

Foissner, W., Wolf, K.W., Yashchenko, V. & Stoeck, T. (2011) Description of *Leptopharynx bromelicola* n. sp. and characterization of the genus *Leptopharynx* Mermod, 1914 (Protista, Ciliophora). *Journal of Eukaryotic Microbiology*, 58 (2), 134–151.
https://doi.org/10.1111/j.1550-7408.2011.00532.x

Foissner, W., Wolf, K., Kumar, S., Xu, Q. & Quintela-Alonso, P. (2014) Five new spathidiids (Ciliophora: Haptoria) from Caribbean tank bromeliads. *Acta Protozoologica*, 53, 159–194.
https://doi.org/10.4467/16890027AP.14.015.1596

Givnish, T.J., Millam, K.C., Berry, P.E. & Sytsma, K.J. (2007) Phylogeny, adaptive radiation, and historical biogeography of Bromeliaceae inferred from ndhF sequence data. *Journal of Systematic and Evolutionary Botany*, 23 (1), 3–26.
https://doi.org/10.5642/aliso.20072301.04

Gouda, E.J., Butcher, D. & Gouda, C.S. (2015) Encyclopaedia of Bromeliads. Version 3. University Botanic Gardens, Utrecht. Available from: http://encyclopedia.florapix.nl/ (accessed 18 November 2020)

Lynn, D.H. (2008) *The ciliated protozoa: characterization, classification, and guide to the literature*. Springer, Dordrecht, 605 pp.

Maguire, Jr.B. (1971) Phytotelmata: biota and community structure determination in plant-held waters. *Annual Reviews in Ecology and Systematics*, 2, 439–464.
https://doi.org/10.1146/annurev.es.02.110171.002255

Malfatti, E. (2019) *Variação altitudinal da comunidade de invertebrados aquáticos em bromelias dos gêneros Vriesea* spp. *Gaudich. e Aechmea gamosepala Wittm. na Serra Geral do Sul do Brasil*. Master Thesis, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, 46 pp.

Mayén-Estrada, R., Reyes-Santos, M. & Aguilar-Aguilar, R. (2014) Biodiversity of Ciliophora in Mexico. *Revista Mexicana de Biodiversidad*, 85 (Supplement), 34–43. https://doi.org/10.7550/rmb.31993

Morrone, J.J. (2017) *Neotropical biogeography: regionalization and evolution*. CRC Press, Taylor & Francis Group, Boca Raton, Florida, 282 pp. [https://lccn.loc.gov/2016045862]

Oertel, A., Klaus, W., Khaled, A.R. & Foissner, W. (2009) Revision of the genus CoriplitesFoissner, 1988 (Ciliophora: Haptorida), with description of Apocoriplitesnov. gen. and three new species. *Acta protozoologica*, 47 (3), 231–246.

Omar, A. & Foissner, W. (2011) Description of *Leptopharynx bromeliophilus* nov. spec. and *Leptopharynx australiensis* nov. spec. (Ciliophora, Nassulida). *Acta Protozoologica*, 50, 89–103.

Paz, N. (1980) Estudio bioecológico en *Guzmania* sp. (Bromeliaceae) y *Heliconia bihai* (Musaceae) en un bosque pluvial del Choco. *Actualidades Biológicas*, 9 (32), 31–50.

Sabagh, L.T., Dias, R.J.P., Branco, C.W.C. & Rocha, C.F.D. (2011) News records of phoresy and hyperphoresy among treefrogs, ostracods, and ciliates in bromeliad of Atlantic forest. *Biodiversity and Conservation*, 20 (8), 1837–1841. https://doi.org/10.1007/s10531-011-0050-z

Weisse, T., Scheffel, U., Stadler, P. & Foissner, W. (2013a) Functional ecology of the ciliate *Glaucomides bromelicola*, and comparison with the sympatric species *Bromeliothrix metopoides*. *Journal of Eukaryotic Microbiology*, 60, 578–587. https://doi.org/10.1111/jeu.12063

Weisse, T., Scheffel, U., Stadler, P. & Foissner, W. (2013b) *Bromeliothrix metopoides*, a boom and bust ciliate (Ciliophora, Colpodea) from tank bromeliads. *European Journal of Protistology*, 49 (3), 406–419. https://doi.org/10.1016/j.ejop.2013.02.001

DISCUSIÓN GENERAL Y CONCLUSIONES

Las bromeliáceas son un elemento conspicuo de la flora neotropical siendo relevantes desde el punto de vista ecológico por su papel como microambientes. Se distribuyen en todos los países de América excepto Canadá, y México es un centro de especiación para esta familia, en donde se han identificado 422 especies de bromelias y ocho taxones infraespecíficos (Espejo-Serna & López-Ferrari, 2018), de las cuales 40% (180 aproximadamente) presentan morfología tipo tanque; de éstas, solo en 27 especies se han estudiado los ciliados que habitan dentro de ellas (Durán-Ramírez & Mayén-Estrada, 2018; Durán-Ramírez *et al*., 2015, 2019, 2020), lo cual denota la falta de estudios ciliatológicos en este tipo de ambientes.

Dentro de una bromelia, se pueden reconocer tres hábitats para los ciliados: (1) la columna de agua que se deposita entre las hojas y que dan lugar a la formación del tanque, (2) los detritos acumulados en el fondo del tanque y entre las bases de las hojas coalescentes de la planta y (3) como epibiontes sobre el cuerpo de invertebrados (Foissner *et al*., 2003). En este estudio, los ciliados se identificaron en la columna de agua y entre los detritos. Una aportación dada a conocer en el presente estudio fue que las bromelias sin morfología tanque que no forman una fitotelma, como las del género *Bromelia* del bosque tropical caducifolio de la Reserva de la Biósfera Chamela Cuixmala y de la vegetación de dunas costeras en Veracruz, representan microhábitats donde también se establecen comunidades de ciliados. Las especies de estas comunidades, muchas de las cuales son comunes en suelos, colonizaron bromelias de este género utilizando los recursos disponibles como la materia orgánica húmeda acumulada entre las bases de las hojas, raíces, así como entre los remanentes de las inflorescencias en descomposición (Durán-Ramírez & Mayén-Estrada, 2018; Durán-Ramírez *et al*., 2019).

Recientemente, se han publicado algunos inventarios sobre la presencia de ciliados en especies de bromelias de Brasil, Ecuador, Jamaica, República Dominicana y Venezuela y datos aislados se han mencionado a partir de bromelias de Chile, Colombia, Costa Rica y Perú (Buosi *et al*., 2014, 2015; Durán-Ramírez *et al*., 2015; Dunthorn *et al*., 2012; Foissner, 2016; Foissner *et al*., 2003). En México, el número de especies de ciliados de bromelias previamente registrado, incluyendo las que se dan a conocer en la presente tesis, equivalen casi al 6% del total de especies documentadas en el país (Mayén-Estrada *et al.*, 2019).

De manera comparativa, se observó que el número de especies de ciliados identificados para las bromelias de la Reserva de la Biósfera de Chamela Cuixmala (Durán-Ramírez & Mayén-Estrada,

2018), así como en las poblaciones de bromelias distribuidas a lo largo de un gradiente de elevación del Centro de Veracruz (Durán-Ramírez *et al*., 2019) fue menor en comparación con las 61 especies registradas en el año 2009 en una población de *Tillandsia heterophylla* en plantaciones de café y remanentes de bosque mesófilo de montaña (Durán-Ramírez *et al*., 2015); valores más bajos de riqueza específica (19) fueron reportados por Paz (1980) en una población de bromelias epífitas del género *Guzmania* del Chocó en Colombia. En contraste, valores más altos de riqueza específica fueron obtenidos en una población de *Aechmea distichantha* por Buosi *et al*. (2014, 2015) a lo largo de la ribera del Río Paraná al sur de Brasil, cuya comunidad de ciliados estuvo conformada por 92 especies. Es constante que en las bromelias, las clases de ciliados Colpodea, Oligohymenophorea y Spirotrichea son las que agrupan al mayor número de especies.

Previamente se había documentado que algunos géneros de amplia distribución y que son frecuentes en cuerpos de agua dulce, no colonizan bromelias, como lo es *Paramecium* Müller, 1773, *Frontonia* Ehrenberg, 1838, *Glaucoma* Ehrenberg, 1830 y *Trithigmostoma* Jankowski, 1967, ya que hasta hace poco, ninguna especie de estos géneros había sido registrada en bromelias (Dunthorn *et al*., 2012), pero Buosi *et al*. (2014) identificaron a *Paramecium multimicronucleatum* en *Aechmea distichantha* al sur de Brasil. En el presente estudio, se observaron dos especies de *Frontonia* pertenecientes a la clase Oligohymenophorea, habitando en bromelias sin morfología tipo tanque y cuya dieta está constituida por detritos y esporas que se acumulan en las bromelias.

Leptopharynx bromeliophilus y *Gonostomum bromelicola*, especies de las clases Nassulida y Spirotrichea respectivamente, tienen una distribución restringida a México y las Antillas, mientras que *Cotterillia bromelicola* (Spirotrichea) se restringe a bromelias de México y a algunos ambientes terrestres en Costa Rica (Foissner & Stoeck, 2011). Aún más restringida, es la distribución de *Paraoxytricha quadrinucleata* (Spirotrichea), descrita en una población de *Tillandsia heterophylla*, cuya localidad tipo se encuentra en Xalapa, Veracruz (Foissner, 2016). Otras especies que no son exclusivas de bromelias, pero que hasta ahora sólo se han registrado en el Neotrópico, son *Paracolpoda lajacola* (Colpodida), la cual se distribuye solo en la porción del hemisferio Norte, desde México hasta Venezuela (Foissner, 2016), y *Bresslauides terricola*, un colpódido que también habita en otros continentes, pero en el Neotrópico, ha mostrado una distribución restringida a la porción del hemisferio Norte. Altitudinalmente, resalta la distribución de *Fragmocirrus espeletiae* (Spirotrichea), cuyo hábitat en donde se describió se encuentra por encima de los 4,000 metros (Foissner, 2000) y se observó únicamente en bromelias del bosque mesófilo de montaña en Hidalgo a una elevación de 1400 metros de altitud (Durán-Ramírez *et al*., 2020).

Los ambientes donde se han registrado los ciliados en las bromelias incluyen parques nacionales y reservas de la biósfera con distintos tipos de vegetación como el bosque tropical caducifolio, bosque mesófilo de montaña, bosque tropical perennifolio y encinares; también sobre los márgenes de ríos, plantaciones de café y algunos jardines botánicos (Buosi *et al*., 2014, 2015; Durán-Ramírez *et al*., 2015; Foissner, 2016; Foissner *et al*., 2003). Sin embargo, existen hábitats propicios tanto en México como en una veintena más de países neotropicales donde se distribuyen las bromeliáceas los cuales aún no han sido considerados.

Los estudios ecológicos de ciliados en bromelias son escasos, pero se han abordado algunos aspectos y algunas variables ambientales y fisicoquímicas que posiblemente influyen sobre la composición de la comunidad, tal y como lo es en primer lugar, la presencia de agua acumulada al interior de las plantas con morfología tipo tanque. Buosi *et al.* (2014) demostraron que la cercanía de las bromelias a cuerpos de agua dulce como ríos, propicia que ciertas especies de ciliados dulceacuícolas sean capaces de colonizarlas. Respecto a la estacionalidad, algunos trabajos refieren que la riqueza específica de ciliados de las bromelias es mayor durante la temporada seca, mientras que otros han documentado que es durante la temporada húmeda (Buosi *et al*., 2014, 2015; Durán-Ramírez *et al*., 2015; Foissner *et al*., 2003); también se ha documentado que la temperatura del agua y la altitud sobre el nivel del mar son dos variables que operan sobre la composición de la comunidad de ciliados que a su vez, a nivel local puede ser diferente con respecto al tipo de vegetación en donde habitan las bromelias (Durán-Ramírez *et al*., 2019).

La presencia de ciliados en bromelias puede explicarse también debido a la alternancia entre periodos de sequía y humedad, al aislamiento parcial respecto al medio circundante, sobre todo en el dosel del bosque y a la competencia intra e interespecífica a la que están sometidos. La existencia de especificidad ciliado-bromelia, es aparentemente inexistente (Dunthorn *et al*., 2012), y por ello la identidad taxonómica de las bromelias no es determinante en la composición de la comunidad de ciliados. Para los ciliados, la relevancia de las bromelias radica en que no hay otro microhábitat con las mismas características, en donde puedan establecerse en tiempo y espacio, e incluso obtener resguardo para mantener poblaciones viables. De manera precisa, se establece que la especificidad que existe es de tipo ecológico, es decir, que las bromelias representan un microhábitat temporal favorable, lo cual cobra mayor relevancia si se considera el hecho de que se trata de un tipo de microhábitat que solo se halla en la Región Neotropical.

Además de bromelias, existen pocas evidencias de la presencia de ciliados en otros puntos del dosel en los bosques tropicales. Bamforth (2007) identificó alrededor de 50 especies de ciliados en el

suelo suspendido formado por musgos en ramas de árboles de un bosque tropical en Puerto Rico, de las cuales, coincidieron nueve especies cosmopolitas observadas en las bromelias del presente estudio, pero ninguna de las consideradas habitantes exclusivas de las bromelias, fueron observadas en este biotopo.

Con los resultados de la presente tesis, se amplía el conocimiento de las comunidades de ciliados en distintas especies de bromelias, principalmente del género *Tillandsia* circunscritas a esta región del Neotrópico, considerando un gradiente de elevación, así como distintos tipos de vegetación característicos de las zonas de montaña del centro y sur de México y bosques tropicales a elevaciones bajas de la Península de Yucatán y de la vertiente del Pacífico. Se concluye que por su distribución restringida al Neotrópico y sus características como microambientes, las bromeliáceas son un modelo de estudio para continuar abordando aspectos sobre diversidad, ecología y distribución de los ciliados.

REFERENCIAS BIBLIOGRÁFICAS

Adl, S. M., Bass, D., Lane, C. E., Lukeš, J., Schoch, C. L., Smirnov, A., Agatha, S., Berney, C., Brownk, M. W., Burki, F., Cárdenas, P., Čepička, I., Chistyakova, L., del Campo, J., Dunthorn, M., Edvardsen, B., Eglit, Y., Guillou, L., Hampl, V., Heiss, A. A., Hoppenrath, M., James, T. Y., Karpov, S., Kim, E., Kolisko, M., Kudryavtsev, A., Lahr, D. J. G., Lara, E., Gall, L. L., Lynn, D. H., Mann, D. G., Massana i Molera, R., Mitchell, E. A. D., Morrow, C., Park, J. S., Pawlowski, J. W., Powell, M. J., Richter, D. J., Rueckert, S., Shadwick, L., Shimano, S., Spiegel, F. W., Torruella i Cortes, G., Youssef, N., Zlatogursky, V. & Zhang, Q. 2019. Revisions to the Classification, Nomenclature, and Diversity of Eukaryotes. *Journal of Eukaryotic Microbiology* 66: 4-119.

Bamforth, S. S. 2007. Protozoa from aboveground and ground soils of a tropical rain forest in Puerto Rico. *Pedobiologia* 50: 515-525.

Buosi, P. R. B., Utz, L. R. P., de Meira, B. R., Segóvia da Silva, B. T., Lansac-Tôha, F. M., Lansac-Tôha, F. A. L. & Velho, L. F. M. 2014. Rainfall influence on species composition of the ciliate community inhabiting bromeliad phytotelmata. *Zoological Studies* 53: 1-12.

Buosi, P. R. B., Cabral, A. F., Utz, L. R. P., Vieira, L. C. G. & Velho, L. F. M. 2015. Effects of seasonality and dispersal on the ciliate community inhabiting bromeliad phytotelmata in riparian vegetation of a large tropical river. *Journal of Eukaryotic Microbiology* 62 (6): 737-749.

Dunthorn, M., Stoeck, T., Wolf, K., Breiner, H. W. & Foissner, W. 2012. Diversity and endemism of ciliates inhabiting Neotropical phytotelmata. *Systematics and Biodiversity* 10 (2): 195-205.

Durán-Ramírez, C. A. & Mayen-Estrada, R. 2018. Ciliate species from tank-less bromeliads in a dry tropical forest and their geographical distribution in the Neotropics. *Zootaxa* 4497 (2): 241-257.

Durán-Ramírez, C. A., García-Franco, J. G., Foissner, W. & Mayén-Estrada, R. 2015. Free living ciliates from epiphytic tank bromeliads in Mexico. *European Journal of Protistology* 51: 15-33.

Durán-Ramírez, C. A., Mayén-Estrada, R. & Romero-Niembro, V. M. 2019. Ciliate community structure in bromeliads of different types of vegetation in eastern Mexico. *Acta Protozoologica* 58 (3): 155-165.

Durán-Ramírez, C. A., Mayén-Estrada, R. & Dias, R. J. P. 2020. Checklist of ciliates (Alveolata: Ciliophora) that inhabit in bromeliads from the Neotripical Region. *Zootaxa* 4895 (1): 1-36.

Espejo-Serna, A. & López-Ferrari, A. R. 2018. La familia Bromeliaceae en México. *Botanical Sciences* 96 (3): 533-554.

Foissner, W. 2000. Notes on ciliates (Protozoa, Ciliophora) from *Espeletia* trees and *Espeletia* soils of the Andean Páramo, with descriptions of *Sikorops espeletiae* nov. spec. and *Fragmocirrus espeletiae* nov. gen., nov. spec. *Studies on Neotropical Fauna* & *Environment* 35: 52-79.

Foissner, W. 2003a. Morphology and ontogenesis of *Bromeliophrya brasiliensis* gen. n., sp. n., a new ciliate (Protozoa: Ciliophora) from Brazilian tank bromeliads (Bromeliaceae). *Acta Protozoologica* 42: 55-70.

Foissner, W. 2003b. Morphology and ontogenesis of *Lambornella trichoglossa* nov. spec., a new tetrahymenid ciliate (Protozoa: Ciliophora) from Brazilian tank bromeliads (Bromeliaceae). *European Journal of Protistology* 39: 63-82.

Foissner, W. 2010. Life cycle, morphology, ontogenesis, and phylogeny of *Bromeliothrix metopoides* nov. gen., nov. spec., a peculiar ciliate (Protista, Colpodea) from tank bromeliads (Bromeliaceae). *Acta Protozoologica* 49 (3): 159-193.

Foissner, W. 2016. Terrestrial and semiterrestrial ciliates (Protozoa, Ciliophora) from Venezuela and Galapagos. *Denisia* 35: 1-912.

Foissner, W. & Stoeck, T. 2011. *Cotterillia bromelicola* nov. gen., nov. spec., a gonostomatid ciliate (Ciliophora, Hypotricha) from tank bromeliads (Bromeliaceae) with *de novo* originating dorsal kineties. *European Journal of Protistology* 47: 29-50.

Foissner, W., Strüder-Kypke, M., van der Staay, G., Moon-van der Staay, S. & Hackstein, J. 2003. Endemic ciliates (Protozoa, Ciliophora) from tank bromeliads (Bromeliaceae): a combined morphological, molecular, and ecological study. *European Journal of Protistology* 39: 365-372.

Foissner, W., Chao, A. & Katz, L. A. 2007. Diversity and geographic distribution of ciliates (Protista: Ciliophora). *Biodiversity and Conservation* 17: 345-363.

Foissner, W., Wolf, K. W., Yashchenko, V. & Stoeck, T. 2011. Description of *Leptopharynx bromelicola* n. sp. and characterization of the genus *Leptopharynx* Mermod, 1914 (Protista, Ciliophora). *Journal of Eukaryotic Microbiology* 58: 134-151.

Frank, J. H. & Lounibos, L. P. 1987. Phytotelmata: Swamps or islands? *Florida Entomologist* 70: 14-20.

Frank, J. H., Sreenivasan, S., Benshoff, P. J., Deyrup, M. A., Edwards, G. B., Halbert, S. E., Hamon, A. B., Lowman, M. D., Mockford, E. L., Scheffrahn, R. H., Steck, G. J., Thomas, M. C., Walker, T. J. & Welbourn, W. C. 2004. Invertebrate animals extracted from native *Tillandsia* sp. (Bromeliales: Bromeliaceae) in Sarasota County, Florida. *Florida Entomologist* 87: 176-185.

Givnish, T. J., Millam, K. C., Berry, P. E. & Sytsma, K. J. 2007. Phylogeny, adaptive radiation, and historical biogeography of Bromeliaceae inferred from ndhF sequence data. *Journal of Systematic and Evolutionary Botany* 23 (1): 3-26.

Givnish, T. J., Barfuss, M. H. J., van Ee, B., Riina, R., Schulte, K., Horres, R., Gonsiska, P. A., Jabaily, R. S., Crayn, D. M., Smith, J. A. C., Winter, K., Brown, G. K., Evans, T. M., Holst, B. K., Luther, H., Till, W., Zizka, G., Berry, P. E. & Sytsma, K. J. 2011. Phylogeny, adaptative radiation and historical biogeography in Bromeliaceae. Insights from an eight- locus plastid phylogeny. *American Journal of Botany* 98 (5): 872-895.

Gouda, E. J., Butcher, D. & Gouda, C. S. 2015. Encyclopaedia of Bromeliads, Version 3. University Botanic Gardens, Utrecht. http://encyclopedia.florapix.nl/. University Botanic Gardens, Utrecht (acceso: 27/nov/2017).

Jones, E. E. 1974. The Protozoa of Mobile Bay, Alabama. University of South Alabama Monographs, Alabama, 1 (1): 113 pp.

Luther, H. E. 2006. An alphabetical list of Bromeliad binomials. The Marie Selby Botanical Gardens. Sarasota, Florida. The Bromeliad Society International, Florida, USA, 124 pp.

Lynn, D. H. 1988. Cytoterminology of cortical components of ciliates: somatic and oral kinetids. *BioSystems* 21 (3): 299-307.

Lynn, D. H. 2008. The ciliated protozoa: characterization, classification, and guide to the literature. Springer, Dordrecht. Netherlands, 605 pp.

Lynn, D. H. 2017. *Ciliophora*. En: Archibald, J. M., Simpson, A. G. B. & Slamovits, C. H. (Eds.). Handbook of the protists. Springer, Switerland, 679-730.

Maguire Jr, B. 1971. Phytotelmata: biota and community structure determination in plant-held waters. *Annual Reviews in Ecology and Systematics* 2: 439-464.

Mayén-Estrada, R., Reyes-Santos, M., Durán-Ramírez, C. A., Medina-Durán, J. H., Olvera-Bautista, J. F. Y., Vicencio-Aguilar, M. E. & Romero-Niembro, V. M. 2019. Protistas ciliados y flagelados heterótrofos. Proyecto KT003. CONABIO.

Omar, A. & Foissner, W. 2011. Description of *Leptopharynx bromeliophilus* nov. spec. and *Leptopharynx australiensis* nov. spec. (Ciliophora, Nassulida). *Acta Protozoologica* 50: 89-103.

Omar, A. & Foissner, W. 2012. Neotypification and ontogenesis of *Leptopharynx costatus costatus* Mermod, 1914. *Journal of Eukaryotic Microbiology* 59 (3): 268-286.

Paz, N. 1980. Estudio bioecológico en *Guzmania* sp. (Bromeliaceae) y *Heliconia bihai* (Musaceae) en un bosque pluvial del Choco. *Actualidades Biológicas* 9 (32): 31-50.

Sabagh, L. T., Dias, R. J. P., Branco, C. W. C. & Rocha, C. F. D. 2011. News records of phoresy and hyperphoresy among treefrogs, ostracods, and ciliates in bromeliad of Atlantic forest. *Biodiversity and Conservation* 20 (8): 1837-1841.