Domingo Lago-Barcia

Land planarian (Platyhelminthes, Tricladida) diversity and endemisms in the Atlantic forest

Diversidade e endemismos na mata Atlântica de planárias terrestres (Platyhelminthes, Tricladida)

São Paulo

2021

Domingo Lago-Barcia

Land planarian (Platyhelminthes, Tricladida) diversity and endemisms in the Atlantic forest

Diversidade e endemismos na mata Atlântica de planárias terrestres (Platyhelminthes, Tricladida)

Tese apresentada ao Instituto de Biociências da Universidade de São Paulo, para a obtenção de Título de Doutor em Ciências Biológicas, na Área de Zoologia.

Orientador: Prof. Dr. Fernando Jesús Carbayo Baz

São Paulo

2021

Ficha catalográfica elaborada pelo Serviço de Biblioteca do Instituto de Biociências da USP,
com os dados fornecidos pelo (a) autor (a) no formulário:
'https://biblioteca.ib.usp.br/ficha-catalografica/src/ficha.php'

Lago-Barcia, Domingo
Land planarian (Platyhelminthes, Tricladida) diversity and endemisms in the Atlantic forest / Domingo Lago-Barcia ; orientador Fernando Jesus Carbayo Baz -- São Paulo, 2021.
333 p.

Tese (Doutorado) -- Instituto de Biociências da Universidade de São Paulo. Programa de Pós-Graduação em Zoologia.

1. Geoplaninae. 2. Land planarians. 3. Terrestrial flatworms. 4. Taxonomy and Phylogeny. 5. Areas of Endemism. I. Carbayo Baz, Fernando Jesus, orient. II. Título.

Bibliotecária responsável pela catalogação:
Elisabete da Cruz Neves - CRB - 8/6228

Comissão Julgadora

Profa. Dra. Carolina Julia Noreña Janssen (Museo Nacional de Ciencias Naturales de Madrid (MNCN))

Profa. Dra. Natalia Veronica Bulnes (Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET))

Prof. Dr. Lisandro Hector Luis Negrete (Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET))

Orientador Prof. Dr. Fernando Jesus Carbayo Baz (Instituto de Biociências (USP))

Dedicado a todos
mis seres queridos,
estén o no presentes
en mi vida.

Agradecimentos

Gostaria de agradecer a todos que participaram direta ou indiretamente na elaboração desta tese. Devido à pandemia, foram cinco anos de trabalho, onde diversas pessoas contribuíram para me ajudar alcançar um título que nunca, nem imaginei, que poderia atingir.

Meu principal agradecimento é para os profissionais que estiveram do meu lado desde o início e para a minha família que sempre apoiou e ajudou no meu caminho como cientista.

O mais profundo agradecimento desta tese vai para o Prof. Dr. Fernando Carbayo. Ele não é unicamente um excelente profissional, pesquisador e professor, mas uma excelente pessoa que sempre esteve do meu lado para ajudar com o que for. É a ele que agradeço a oportunidade de ter vindo ao Brasil, de me doutorar, e de ter evoluído até quem sou hoje. Obrigado.

Lembrando a minha formação como cientista, gostaria de agradecer a todos os excelentes profissionais que me ajudaram nesse caminho, Mr. Connolly, David, Mrs. Hudson, desde cedo já estimularam em mim o carinho e respeito pelo meio ambiente e os seres vivos. À Dr. Prof. María Teresa Aguado, excelente profissional, pesquisadora e professora que sempre acreditou no meu interesse e dedicação. À Dr. Carolina Noreña que agradeço enormemente pelas lições valiosíssimas que me ensinou no MNCN, por me iniciar no mundo das planárias terrestres e por ser membro da banca de defesa desta mesma tese. Gostaria de mencionar outras figuras que partilharam e me ensinaram ao longo da minha carreira, como ao Dr. Fernando Ángel Fernández Álvarez ou ao Dr. Jorge Rodríguez Monter. Obrigado de coração, vocês foram um exemplo a seguir.

Gostaria de agradecer a todas as pessoas que colaboraram neste trabalho e aos seus respectivos laboratórios, sem a ajuda de vocês esta tese não seria nada: Dr. Marta Álvarez Presas, Dra. Marta Riutort, Dr. Marcio Da Silva, Dr. Luis Américo Conti, MSc. Marcos Da Silva, Dra. Ana Laura Almeida, e todos os membros do laboratório, os técnicos Geison Castro, Lucas Beltrami, Manuel Junior.

Agradeço aos membros da Banca de Defesa deste doutorado desde já, Dr. Lisandro Negrete, Dra. Verónica Bulnes e Dra. Carolina Noreña.

Agradeço à Universidade de São Paulo (USP) por permitir este doutorado acontecer. Aos membros da Pós-Graduação do Instituto de Biociências por todo, e por saber lidar com alguém que esqueceu de todo prazo…

Ao Conselho Nacional de Desarrollo Científico e Tecnológico (CNPq) e à Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) pela disponibilização do auxílio financeiro indispensável para realização da pesquisa, nas formas de bolsa regular (152971/2016-5), reserva técnica e Projeto FAPESP 2019/12357-7. Agradeço à Coordenação de Aperfeiçoamento de Nível Superior (CAPES) por possibilitar os Editais de CAPES-PROEX com auxilio financeiro de 2016-2020.

No âmbito pessoal, agradeço a todos que me receberam no Brasil e especialmente a quem se preocupou comigo e cuidou de mim. Esta é uma pequena lista incluindo alguns de vocês: Mariana Cardoso, Pedro Gadelha, Jair Cardoso, María Aparecida Cardoso, Thiago Meneses, Ligia Santos, Danilo Da Silva, Deborah Borges, Guilherme Pontes, Rodrigo de la Paz, Alcides el Fino, Stella Legnaioli e Kika Legnaioli. Vocês são mais que família. Agradeço a toda minha gente da Espanha, apesar de estar longe sempre contei com o apoio de vocês.

Pudulito y Mudulita, vocês foram, são e sempre serão os mais importantes. Obrigado por TODO.

Index

General introduction……9

- Land flatworm classification and distribution……..9

- Geoplaninae Phylogeny……..……...…11

- Biogeography of the Geoplaninae……..……13

- Objectives and justification…….…….…….13

- General Methodologies……...…….…….14

- Thesis organization…….……..……18

Chapter 1
Taxonomic revision of four species of the Neotropical land planarian genera *Cratera* and *Geoplana* (Platyhelminthes, Tricladida) with a description of two new species and an emendation of *Cratera*……..…28

Chapter 2
Revision and description of six species of *Choeradoplana* (Platyhelminthes, Tricladida), with an emendation to the genus…….……73

Chapter 3
Phylogenetic relationships of the Geoplaninae land planarians (Platyhelminthes, Tricladida) as assessed with a total evidence approach.……139

Chapter 4
Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest……...……...187

Chapter 5
Areas of endemism of land planarians (Platyhelminthes, Tricladida) in the Atlantic forest: expanding the study and exploring niche modeling…….…..254

Final considerations…….……331

Resumo/Abstract……..334

General Introduction

Land flatworm classification and distribution

Triclads, or planarians, are free-living platyhelminths, ubiquitous in marine, freshwater and terrestrial habitats. These animals belong to the superorder Continenticola Carranza et al., 1998 which is divided into two superfamilies, Planaroidea Stimpson, 1857 and Geoplanoidea Stimpson, 1858. Geoplanoidea is also divided into two families, namely Dugesiidae Ball, 1975 and Geoplanidae Stimpson, 1857, freshwater flatworms (in part) and the land flatworms, respectively. Land planarians or flatworms (Geoplanidae), present a cosmopolitan distribution, being present in all continents except for Antarctica (Winsoret et al., 1998; Sluys and Riutort, 2018). Among the triclads, land planarians are most abundant in tropical and subtropical forest regions. Land flatworms are oviparous animals that live in humid environments. They are predators of the soil fauna where they live, feeding on earthworms, gastropodes and arthropods as their main prey (Cseh et al., 2017; Boll, 2019).

More than 910 species of Geoplanidae are described (Tyler et al., 2006; Sluys, 2016). Its highest species diversity can be found in the intertropical region, from where they are best known (Sluys, 1998, 1999; Winsor et al. 1998). Geoplanidae is currently subdivided into five subfamilies: Bipaliinae Stimpson, 1857, Microplaninae Pantin, 1953, Rhynchodeminae Graff, 1896, Timyminae Almeida and Carbayo, 2021 and Geoplaninae Stimpson, 1857.

Bipaliin planarians are easily identified by having lateral expansions on their anterior extremity of the body, giving them a head with a fan-shaped appearance. This group presents its highest species richness in Asia and Africa, with records from China, India, Japan, Korea, Madagascar, the Russian Far East and Taiwan (Kawakatsu et al. 2005). Several species were introduced worldwide. The subfamily is divided into four genus, namely: *Bipalium* Stimpson, 1857; *Diversibipalium* Kawakatsu et al., 2002; *Humbertium* Ogren and Sluys, 2001; and *Novibipalium* Kawakatsu, Ogren and Froehlich, 1998 (Sluys and Riutort, 2018).

Microplaninae planarians present their highest known diversity in Europe (Mateos et al., 2017) but they present a cosmopolitan distribution. This group is characterized by having a small body, more or less cylindrical and one pair of small eyes in the anterior extremity (Winsor, 1998). The subfamily is divided into eight genera, namely: *Amblyplana* Von Graff, 1896; *Diporodemus* Hyman, 1938; *Geobenazzia* Minelli, 1974; *Incapora* Du Bois-Reymond Marcus, 1953; *Microplana* Vejdovsky, 1890; *Othelosoma* Gray, 1869; *Pseudoarticorylus* Ikeda, 1911; and *Statomicroplana* Kawakatsu et al., 2003 (Sluys et al., 2009).

Rhynchodemin planarians are also cosmopolitan, and widely distributed throughout Europe (Mateos et al., 1998). They comprise several small species with an elongated and almost cylindrical body, a rounded anterior extremity provided with a single pair of eyes. At this time, Rhynchodeminae is composed by seven tribes, namely, Anzoplanini Winsor, 2006; Argaplanini Winsor, 2011 (monogenus tribe); Caenoplanini Ogren and Kawakatsu, 1991; Eudoxiatopoplanini Winsor, 2009 (monogenus tribe); Pelmatoplanini Ogren and Kawakatsu, 1991; and Rhynchodemini Heinzel, 1929.

Timymin planarians are bipaliin-like organisms in that they present lateral head expansions similar to those found in the Bipaliinae. The distribution of Timyminae is limited to the Chilean region. The subfamily only possesses one genus, namely *Timyma* (Froehlich, 1978) (Almeida et al., 2021).

Geoplaninae, restricted to the Neotropical region, is the main focus group of this PhD thesis. This group is the most speciose subfamily of land planarians (Winsor et al., 1998). Geoplaninae is comprised of land planarians that posses a broad ciliated creeping sole covering most of the ventral surface, a mouth immediately behind the midbody, dorsal testes, well developed subepithelial or cutaneous longitudinal musculature arranged in bundles, and may present additional parenchymal muscle layers and organized in longitudinal fibres, either dorsally and ventrally to the intestine, or as a tube around it (Almeida et al., 2019). Small animals tend to be cylindrical and eyes may be absent. This group presents a high morphological variability, externally and internally, ranging from animals a few millimeters long (e.g. *Xerapoa*) to 30 cm (e.g. *Obama eudoximariae*); from eyes with numerous eyes spread onto the entire dorsum (e.g. *Cratera*), to no eyes at all (*Geobia*); from a anatomically non-differentiated cephalic region (e.g. *Matuxia*), to a rolled up anterior extremity, laterally dilated (e.g.

Choeradoplana). The internal organs, mostly the pharynx and copulatory apparatus also vary in shape. This copulatory apparatus is especially important for the identification of the species and the diagnosis of the genera. Composition and organization of the cutaneous and parenchymatic muscle systems are also key attributes for generic diagnoses. Currently Geoplaninae comprises 29 genera (See Tab. 1).

Geoplaninae phylogeny

The subfamily Geoplaninae is the most speciose taxon inside the Geoplanidae. Probably the systematics of the Geoplaninae is the best known among the subfamilies of Geoplaninae. Since early on, several authors dedicated their efforts to produce classifications and phylogenetic studies of the land flatworms using morphological characteristics (Hallez, 1892, 1893, 1894; Graff, 1896, 1899; Pantin, 1953; Meixner, 1928; Marcus, 1953; Froehlich, 1967; Winsor et al., 1998, and unpublished thesis: Winsor, 2003; Carbayo, 2003; Grau, 2010; Amaral, 2017) and were able to point out the monophyly of the Geoplaninae from early on (Grau, 2010; Amaral, 2017).

The subfamily Geoplaninae was molecularly analised for the first time by Álvarez-Presas et al. (2008) who showed Geoplaninae's monophyly, although the study was carried out using a low representativeness of Geoplanin species, i.e., five species of two genera. Later molecular studies focusing more on the Geoplaninae, determined more robust genera relationships (Carbayo et al., 2013), and were able to identify that most genera inside the subfamily were monophyletic and in concordance with previous morphological studies and observations (Carbayo et al., 2013). Since Carbayo et al., (2013) further phylogenies at various levels of coverage and detail for the taxons composing the Geoplaninae have been proposed, but most of them focused on a specific taxon and did not analise details of the internal relationhips (Álvarez-Presas et al., 2014, 2015; Lemos et al., 2014; Rossi et al., 2016; Harrath et al., 2016; Almeida et al., 2019; Negrete et al., 2019; Lago-Barcia et al., 2015, 2018, 2021; Iturralde *et al*., 2021; Araújo et al., 2020).

Tab. 1. Current classification and number of species ineach of the genera inside the subfamily Geoplaninae.

Genus	Authority	N.º of species in the genus
Amaga	Ogren and Kawakatsu, 1990	10
Barreirana	Ogren and Kawakatsu, 1990	2
Bogga	Grau and Sluys, 2012	1
Cephaloflexa	Carbayo and Leal-Zanchet, 2003	3
Choeradoplana	Graff, 1896	23
Cratera	Carbayo et al., 2013	23
Difroehlichia	Leal-Zanchet and Marques, 2018	1
Geobia	Diesing, 1862	1
Geoplana	Schultze and Müller, 1857	65
Gigantea	Ogren and Kawakatsu, 1990	13
Gusana	Froehlich, 1978	3
Imbira	Carbayo et al., 2013	4
Inkayalia	Negrete et al., 2020	1
Issoca	Froehlich, 1954	6
Liana	Froehlich, 1978	1
Luteostriata	Carbayo, 2010	10
Matuxia	Carbayo et al., 2013	3
Notogynaphallia	Ogren and Kawakatsu, 199	13
Obama	Carbayo et al., 2013	45
Paraba	Carbayo et al., 2013	19
Pasipha	Ogren and Kawakatsu, 1990	34
Pichidamas	Bulnes, Grau and Carbayo, 2018	1
Piima	Oliveira et al., 2020	1
Polycladus	Blanchard, 1845	1
Pseudogeoplana	Ogren and Kawakatsu, 1990	59
Supramontana	Carbayo and Leal-Zanchet, 2003	2
Wallamapuplana	Negrete et al., 2020	1
Winsoria	Negrete et al., 2019	1
Xerapoa	Froehlich, 1954	4

Biogeography of the Geoplaninae

The identification of Areas of Endemism is a valuable resource to understand the distribution of the diversity of a taxon. Due to the fisiological limitations of the Geoplaninae such as their sensitivity to changes in the conditions of their environment (Carbayo et al., 2002), their highly endemic status in the Atlantic forest due to their low vagility and dependence on humidity (Sluys, 1995; Winsor et al., 1998) and the fact that they are are endemic to relatively small areas (Sluys, 1999), land flatworms are considered an optimal taxonomic group to carry out the idetification of small and fine-scaled Areas of Endemism inside the Atlantic forest (Lago-Barcia et al., 2020). Further on, we can compare these endemic patterns with other taxons presenting similar fisiological limitations to analyse the consistency/robustness of the areas defined.

Objectives and justification

The general objective throughout the course of these PhD thesis was to contribute to the knowledge in taxonomy, phylogeny and areas of endemism of the land planarians with an emphasis on the organisms inhabiting the Atlantic forest. Beyond our intrinsic knowledge on land flatworms, the understanding of the species richness and evolutionary relationships amongst species, as well as their distribution in space and time, can aid us improve the actions needed for conservation purposes inside the Atlantic forest. The correct conservation of natural ecosystems depends on the knowledge we have on the species that inhabit these areas.

To produce a natural classification of the Geoplaninae, it is important to describe new species and to revise the ones already described in order to keep our knowledge on the animal group updated. Several new species, representatives of rare lineages, or with peculiar morphological characters were chosen to be described, to expand the current knowledge and understanding on morphological variability inside the group and certainly to expand the known species diversity for these regions. Therefore, a new approach, with a broader methodological procedure, namely a Total Evidence Analysis, using larger taxon sampling and higher number of molecular markers, was used to achieve a more robust and resolved phylogeny of the Geoplaninae. Finally, by analysing

areas of endemism and biogeographic processes that may have given birth to new planarian species we may hypothesize the processes involved in the speciation of the flatworms inside study area (Lago-Barcia et al., 2020).

General objective: Carry out systematic studies of Neotropical land planarians, focusing on endemism and biodiversity in the Brazilian Atlantic forest.

Specific objectives:

1. Produce an inventory of the morphospecies collected in the 12 sampling sites by means of histological and molecular analyses.
2. Propose evolutionary relationships of representative lineages of Geoplaninae.
3. Describe selected new species based on criteria of morphological diversity and representativeness of rare lineages.
4. Test for identification of Areas of Endemism.

General methodologies

Specimen collection and sampling area

Land planarians were collected in areas covered with Atlantic Forest from the States of Espirito Santo to Rio Grande do Sul, Brazil, between the years 2007 and 2020 by Fernando Carbayo and collaborators. The field data was predominantly compiled from 12 intensively sampled areas which are conservation areas (Fig. 1), meaning the areas were sampled for ~200 person-hour. These intensively sampled areas are, from North to South, Reserva Biológica Augusto Ruschi (Santa Teresa, State of Espírito Santo), Parque Estadual do Desengano (Santa Maria Madalena, state of Rio de Janeiro), Parque Nacional da Serra dos Órgãos (Teresópolis, state of Rio de Janeiro), Parque Nacional da Serra da Bocaina (São José do Barreiro, state of São Paulo), Estação Biológica de Boraceia (Salesópolis, state of São Paulo), Parque Estadual da Serra da

Cantareira (São Paulo, state of São Paulo), Parque Estadual de Intervales (State of São Paulo), Parque Nacional de Saint-Hilaire/Lange (State of Paraná), Parque Nacional da Serra do Itajaí (State of Santa Catarina), Parque Estadual da Serra do Tabuleiro (State of Santa Catarina), Parque Nacional de São Joaquim (State of Santa Catarina) and Floresta Nacional de São Francisco de Paula (State of Rio Grande do Sul).

Specimens were collected during daylight hours from under rocks and fallen logs and leaves. Geographic coordinates of collecting sites of these specimens were recorded either with Garmin eTrex GPS device, or were taken from Googlemaps.

Specimen preparation

After collection, the flatworms were observed, photographed *in vivo* and then killed using boiling water. Before fixing them for histological studies, a small piece of the animal was removed and preserved in absolute ethanol and stored at -20ºC.

The parts destined for histological studies were fixed in 10% formaldehyde, and subsequently preserved in 80% ethanol. The samples were progressively dehydrated in an ascending series of ethanol, cleared in clove oil and embedded in Paraplast® Tissue Embedding Medium. In the laboratory, photographs from the specimens cleared in clove oil were taken using a stereomicroscope with a camera attached. Tissue blocks were sectioned at 7-5 μm intervals using a retracting rotary microtome, affixed with albumin-glycerol (1:1) on glass slides placed on a hot plate and stained with the method Mallory-Heidenhain modified by Cason (1950). Reconstructions of the copulatory apparatus were carried out from the histological sections from the specimens. Figures of dorsal or sagittal views are orientated so that the anterior end of the body is to the left throughout the whole thesis.

Specimens from E. M. Froehlich's collection were used for some studies. This material was probably fixed with Susa. Specimens collected in 2005 or later were fixed in 100% ethanol or in 10% formalin buffered solution.

Species identification

The specimens studied throughout the thesis were diagnosed by either only their external aspect (for known and characteristic species regarding size, shape and color of

the body) or through external aspect and morphological details of the cephalic region, the pharynx and the copulatory apparatus, examined on the histological glass slides produced following the previous indications. Some specimens could not be identified either because of their poor state of conservation or due to their immature developmental status and were not further considered in any of the presented studies.

In the laboratory, specimens were initially identified as morphospecies when the species was different to any other known species (described or not in the literature), according to their external appearance. Their histological sections of the cephalic region, pharynx and copulatory apparatus of one or more representatives of most morphospecies were prepared whenever possible and examined with a light microscope. The internal morphology was compared against that of other morphospecies and known species to check for conspecificity. These morphospecies were finally classified into one of the following five categories: known species (e.g., *Geoplana chita* Schultze & Müller, 1857), undescribed species of a known genus (e.g., *Geoplana* sp. 1), undescribed species of an undescribed genus (e.g., gen. 1 sp. 1), undescribed species of an undetermined genus (e.g., Geoplaninae 1), and uncertain species of a known genus (e.g., *Imbira* cf. *marcusi*, *Luteostriata* sp.).

DNA extraction, amplification and sequencing

Specimens of species included in the different chapters, had their genomic DNA extracted using the Wizard® Genomic DNA Purification Kit (Promega, Madison, WI, USA) or following a standard ammonium acetate extraction protocol modified from Miller et al. (1988). Six DNA regions were amplified in total: the mitochondrial cytochrome oxidase I gene (COI, ~900 pb), and five nuclear regions: three of them corresponding to the genes in the ribosomal cluster 18S rDNA type II (18S, ~1600 pb) and 28S rDNA (28S, ~1700 pb), the gene encoding for the elongation factor 1-alpha gene (EF, ~650 pb), a molecular marker corresponding to the Rho2-GTPase region (named Tnuc813 following Araujo et al., 2020) and a new nuclear marker named DOM5 tested for the first time in Chapter 3.

The design of primers (DOM5) was done using scaffolded reads from a low coverage genome sequencing using the software DOMINO (Development Of Molecular

Markers In Non-model Organisms) (Frías-López et al., 2016). The DNA fragment amplified by the DOM5 primers, turned out to correspond to the sequence of the heat shock protein 70 (hsp70) and not to be an anonymous marker.

Primers used for the present studies and PCR annealing temperatures are presented in each chapter. Standard PCR reactions were performed using Go Taq® DNA polymerase (Promega) in a total volume of 25 µl, which included 0.5 ml of each primer (10 mM) and 2 ml of template DNA. Amplification products were purified using a vacuum manifold (Multiscreen®HTS Vacuum Manifold, Millipore Corporation, Billerica, MA 01821, USA) or using ExoSAP-IT (Affymetrix, OH) before Sanger sequencing in Macrogen Europe or in the Departamento de Botánica of the Instituto de Biociencias of the University of São Paulo. The same primers were used for PCR amplification and sequencing always. The chromatograms were checked for quality and the contigs obtained with Geneious 10.2.6 (Biomatters, http://www.geneious.com) and with SeqMAN (DNAstar).

Phylogenetic analyses

Newly obtained sequences were aligned with sequences from the GenBank database when possible and necessary, building molecular datasets. A *Concatenated* dataset was also built for Chapter 3, by concatenating the six genes (COI, 28S, 18S, EF, Tnuc813, DOM5). Outgroups were specific for each study (see methodological procedures for each chapter).

Alignements were all carried out using the online version of the software MAFFT v7 (Katoh & Standley, 2013), and using the G-INS-i method and the default settings. Datasets with encoding genes (COI, EF, Tnuc813 and DOM5) were aligned based on the amino acid translation as guide, using the mitochondrial genome of Echinoderms and Platyhelminthes (codon table number 9) for the COI dataset, and the universal codon table for the other datasets (EF, Tnuc813 and DOM5). Introns present in the Tnuc813 dataset were aligned independently using MAFFT. Alignments were revised manually in BioEdit v7.2.5 (Hall, 1999) to check for possible errors.

PartitionFinder2 ver. 2.1.1 software (Lanfear et al. 2016) on XSEDE (CIPRES Gateway to Science (Miller et al. 2010) was used to discover the partitions and the

evolutionary models which best fited the nucleotide datasets under the Akaike Information Criterion corrected (AICc) (Hurvich and Tsai 1989). The different alignments were analysed under the Maximum Likelihood inference using the software IQtree2 v2.1.2 (Nguyen et al., 2015) with 10,000 ultrafast bootstrap (UFB) replicates, or using RaxML 7.2.+ software (Stamatakis 2006) available on the CIPRES Science Gateway platform (Miller et al. 2010). We also estimated the phylogenetic relationships with a Bayesian Inference using MrBayes v. 3.2.7 (Ronquist et al. 2012). The Markov chain Monte Carlo searches were run up to 10,000,000 generations and stoprule activated to stopval = 0.01. Samples were taken every 10,000 generations, discarding the first 25% trees as burn-in, after which the chain reached stationarity, which ensured that the average split frequencies between the runs were less than 1%.

Biogeographic Analyses

Three different biogeographical methodological approaches were used throughout the present Thesis. In order to discover areas of endemism we analyzed our datasets using two methodologies: an Endemicity Analysis, which uses a heuristic algorithm of the software NDM/VNDM (Szumik et al., 2002; Szumik & Goloboff, 2004), and a Geographical Interpolation of Endemism based on a Kernel interpolation (Oliveira et al., 2015). In depth explanations of both methodologies can be seen in Chapters 4 and 5.

The resulted patterns obtained from the analysis using both methodologies were integrated and evaluated using the combined criteria proposed by DaSilva et al. (2015), whose protocol permits a more precise delimitation of the areas of endemism identified in the study.

Thesis organization

The original contributions of this Thesis are organized in five Chapters. Each chapter is structured as a scientific article, therefore following the style of the respective journal in which the article was published or intended to be submitted to. The presented chapters are organised in the following order, first dealing with the taxonomical studies, secondly with phylogeny, and finally dealing with the analysis of endemisms of the group.

Chapter 1: Taxonomic revision of four species of the Neotropical land planarian genera *Cratera* and *Geoplana* (Platyhelminthes, Tricladida) with a description of two new species and an emendation of *Cratera*

In Chapter 1, already published in *Zootaxa* (Lago-Barcia & Carbayo, 2018), we revise taxonomically four species of the genera *Cratera* and *Geoplana* (*Cratera crioula, C. joia, Geoplana hina, and G. taxiarcha*) and ascribe all to the genus *Cratera*. We also describe two new species belonging to the genus *Cratera* (*C. arucuia* and *C. picuia*). An emendation of the genus was proposed to encompass the morphological variation observed in the genus.

Chapter 2: Revision and description of six species of *Choeradoplana* (Platyhelminthes, Tricladida), with an emendation to the genus

In Chapter 2, already published in *Zookeys* (Lago-Barcia et al., 2021), we revise two species, one belonging to the genus *Choeradoplana* (*Ch. albonigra*) and the other to the genus *Pseudogeoplana* which we transfered to *Choeradoplana* (*Ch. tristriata*). Graff (1899) also studied another specimen that was considered to be conspecific with *Ch. tristriata*; however it is not conspecific but rather a new species for which we proposed the new name *Pseudogeoplana aevipandemiae*. We also described four new species of the genus (*Ch. eudoxiae, Ch. claudioi, Ch. onae,* and *Ch. riutortae*) and proposed an emendation of the diagnosis of the genus based on the new morphological and molecular evidences.

Chapter 3: Phylogenetic relationships of the Geoplaninae land planarians (Platyhelminthes, Tricladida) as assessed with a total evidence approach

In Chapter 3, not submitted for publication yet, we sequenced six genes (the mitochondrial cytochrome oxidase I gene (COI, ~900 pb), the genes in the ribosomal cluster 18S rDNA type II (18S, ~1600 pb) and 28S rDNA (28S, ~1700 pb), the gene encoding for the elongation factor 1-alpha gene (EF, ~650 pb), a molecular marker

corresponding to the Rho2-GTPase region (named Tnuc813 following Araujo et al., 2020) and a new nuclear marker named DOM5 tested for the first time) and characterised 39 morphological characters of 74 specimens, belonging to 19 Geoplaninae genera in a Total Evidence Analysis. The largest clades in the TE tree as well as the relationships within each deeper clade are overall congruent with previous studies and more robust. Our phylogenetic inference also suggests that some of the morphological characters traditionally used in the diagnoses of the genera are homoplastic or plesiomorphic, although some clades lack high statistical support.

Chapter 4: Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest

In Chapter 4, already published in *PlosOne* (Lago-Barcia et al., 2020), we identify nine Areas of Endemism of land planarians in the southern region of the Atlantic forest (from the State of Rio de Janeiro to the State of Rio grande do Sul) using planarian distributions (570 records from literature and from our own field data) and two methodologies to carry out the analysis (Endemism Analysis and Geographical Interpolation of Endemism integrated through DaSilva's et al. (2015) protocol). Most land planarians revealed to present a very small distributional range evidencing their potential as a good model for fine-scale studies of Areas of endemisms.

Chapter 5: Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Atlantic forest: expanding the study area and exploring niche modeling

In Chapter 5, not submitted yet, we extend the study presented in the previous chapter. The area analysed for Areas of Endemism of land flatworms is extended to northern regions up to the State of Espirito Santo. The number of records used was also increased substantially from 570 records to a total of 1888 records, for 371 species (571 records came from the literature and 1317 from our field data). The biogeographic analysis carried out were Endemicity Analysis and Geographic Interpolation of Endemism, as in the previous chapter, plus a Niche Modelling analysis.

References

Almeida AL, Francoy TM, Álvarez-Presas M, Carbayo F. 2021. Convergent evolution: A new subfamily for bipaliin- like Chilean land planarians (Platyhelminthes). *Zoologica Scripta*.00: 1–9.

Almeida AL, Marques FP, Carbayo F. 2019. 'Endless forms most beautiful': taxonomic revision of the planarian Geoplana vaginuloides (Darwin, 1844) and discovery of numerous congeners (Platyhelminthes: Tricladida). *Zoological Journal of the Linnean Society* 185(1): 1-65.

Álvarez-Presas M, Baguñà J, Riutort M. 2008. Molecular phylogeny of land and freshwater planarians (Tricladida, Platyhelminthes): From freshwater to land and back. *Molecular Phylogeny and Evolution* 47: 555–568.

Álvarez-Presas M, Riutort M. 2014. Planarian (Platyhelminthes, Tricladida) diversity and molecular markers: a new view of an old group. *Diversity* 6: 323–338.

Amaral S. 2017. Taxonomia e filogenia de espécies de Geoplaninae (Platyhelminthes) com ênfase nos gêneros Pasipha Ogren & Kawakatsu, 1990 e Imbira Carbayo et al., 2013. Universidade do Vale do Rio dos Sinos. (unpublished Ph.D. thesis).

Araujo APG, Carbayo F, Riutort M, Álvarez-Presas M. 2020. Five new pseudocryptic land planarian species of Cratera (Platyhelminthes: Tricladida) unveiled through integrative taxonomy. *PeerJ* 8: e9726.

Boll P. 2019. Investigando a ecologia trófica de planárias terrestres neotropicais; ecomorfologia, desenvolvimento e comportamento. Universidade do Vale do Rio dos Sinos. (Unpublished Ph.D. thesis).

Carbayo F, Leal-Zanchet AM, Vieira EM. Terrestrial flatworm (Platyhelminthes: Tricladida: Terricola) diversity vs. man-induced disturbance in a subtropical rainforest from Southern Brazil. Biodivers Conserv. 2002; 11: 1091–1104.

Carbayo, F. 2003. Revisión de *Notogynaphallia* (Platyhelminthes: Tricladida) Ogren & Kawakatsu, 1990. Universidad de Salamanca (unpublished Ph.D. thesis).

Cason, J. E. (1950). A rapid one- step Mallory- Heidenhain stain for connective tissue. Stain Technology, 25(4), 225– 226. https://doi. org/10.3109/10520 29500 9110996

Cseh A, Carbayo F, Froehlich EM. 2017. Observations on food preference of Neotropical labd planarians (Platyhelminthes), with emphasis on *Obama antropophila*, and their phylogenetic diversification. *Zoologia* 34: 1-8.

DaSilva MB, Pinto-da-Rocha R, DeSouza AM. 2015. A protocol for the delimitation of areas of endemism and the historical regionalization of the Brazilian Atlantic Rain Forest using harvestmen distribution data. *Cladistics* 31: 692–705.

Frías-López C, Sánchez-Herrero JF, Guirao-Rico S, Mora E, Arnedo MA, Sánchez-Gracia A, Rozas J. 2016. DOMINO: development of informative molecular markers for phylogenetic and genome-wide population genetic studies in non-model organisms. *Bioinformatics* 32(24): 3753-3759.

Froehlich CG. 1967. A contribution to the zoogeography of Neotropical land planarians. *Acta Zoologica Lilloana* 23: 153-162.

Graff LV. 1896. Ueber die Morphologie des Geschlechtsapparates der Landplanarien. *Verhandllungen der Deutchen Zoologishen Gesellschaft* 6: 75-93.

Graff LV. 1899. Monographie der Turbellarien. II. Tricladida Terricola (Landplanarien). I–XII. Atlas von Achtundfünfzig Tafeln zur Monographie der Turbellarien II. Tricladida Terricola (Landplanarien). Pls I–LVIII. Wilhelm Engelmann, Leipzig, 574 pp.

Grau JH. 2010. Relações filogenéticas entre os gêneros de Geoplaninae (Platyhelminthes, Tricladida) inferidas de caracteres morfológicos. Universidade de São Paulo, São Paulo, Brazil. (Unpublished Master Project).

Hall TA. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. In *Nucleic acids symposium series* Vol. 41, No. 41, pp. 95-98. London: Information Retrieval Ltd., c1979-c2000.

Hallez P. 1893. Catalogue des Turbellariés (Rhabdocoelides, Triclades et Dendrocoelides) du Nord de la France & de la Cote Boulonnaise. *Rev. Biol. Nord. Fra.* 5: 92–107. 135–145.

Hallez, P. 1892. Catalogue des Turbellariés (Rhabdocoelides, Triclades et Dendrocoelides) du Nord de la France & de la Cote Boulonnaise. *Rev. Biol. Nord. Fra.* 4: 301–326. 338–350. 425–456.

Hallez, P. 1894. Catalogue des Rhabdocoelides, Triclades & Polyclades du Nord de la France, 2nd, 239 Lille, France: L. Daniel. + 2 pls

Harrath AH, Mansour L, Lagnika M, Sluys R, Boutin C, Alwasel S, …, Riutort M. 2016. A molecular analysis of the phylogenetic position of the suborder Cavernicola within the Tricladida (Platyhelminthes), with the description of a new species of stygobiont flatworm from Benin. *Zoological Journal of the Linnean Society* 178(3): 482-491.

Hurvich CM, Tsai C-L (1989) Regression and Time Series Model Selection in Small Samples. Biometrika 76: 297–307. https://doi.org/10.1093/biomet/76.2.297

Iturralde GG, Allgayer H, Valiati VH, Leal-Zanchet AM. 2021. Seeing the true colours: three new species of *Obama* (Platyhelminthes: Continenticola) from remnants of Atlantic forest in southern Brazil based on an integrative approach. *Invertebrate Systematics* 35(3): 312-331.

Katoh K, Standley DM. 2013. MAFFT multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology and Evolution* 30(4), 772-780.

Kawakatsu M, Sluys R, Ogren RE (2005) Seven new species of land planarian from Japan and China (Platyhelminthes, Tricladida, Bipaliidae), with a morphological review of all Japanese bipaliids and a biogeographic overview of Far Eastern species. Belgian Journal of Zoology 135(1): 53–77

Lago-Barcia D, Carbayo F. 2018. Taxonomic revision of four species of the Neotropical land planarian genera Cratera and Geoplana (Platyhelminthes, Tricladida) with a description of two new species and an emendation of Cratera. *Zootaxa* 4500(4): 517–542 https://doi.org/10.11646/zootaxa.4500.4.3 PMID: 30486048.

Lago-Barcia D, Fernández-Álvarez FA, Negrete L, Brusa F, Damborenea C, Grande C, Noreña C. 2015. Morphology and DNA barcodes reveal the presence of the non-native land planarian Obama marmorata (Platyhelminthes: Geoplanidae) in Europe. *Invertebrate Systematics* 29: 12–22.

Lago-Barcia D, DaSilva MB, Conti LA, Carbayo F. 2020. Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest. *PLoS ONE* 15(7): e0235949. https://doi.org/10.1371/journal.pone.0235949

Lago-Barcia D, Silva MS, Carbayo F. 2021. Revision and description of six species of Choeradoplana (Platyhelminthes, Tricladida), with an emendation to the genus. *ZooKeys* 1016: 1-48.

Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott B. 2017. PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. *Molecular Biology and Evolution* 34(3): 772-773.

Lemos VSA, Cauduro GPB, Valiati HV, Leal-Zanchet AM. 2014. Phylogenetic relationships within the flatworm genus Choeradoplana Graff (Platyhelminthes: Tricladida) inferred from molecular data with the description of two new sympatric species from Araucaria moist forests. *Invertebrate Systematics* 28(6): 605-627.

Marcus E. 1953. Turbellaria Tricladida. In: Exploration du Parc National de l'Upemba. Mission GF De Witte (1946-1949). *Inst. Parcs Nationaux du Congo Belge* 21: 3-62.

Mateos E, Ronald Sluys, Marta Riutort and Marta Álvarez-Presas. 2017. Species richness in the genus Microplana (Platyhelminthes, Tricladida, Microplaninae) in Europe: as yet no asymptote in sight. *Invertebrate Systematics* 31: 269–301

Mateos, E., Giribet, G., & Carranza, S. (1998). Terrestrial planarians (Platyhelminthes, Tricladida, Terricola) from the Iberian Peninsula: first records of the family Rhynchodemidae, with the description of a new Microplana species. *Contributions to Zoology*, *67*(4), 267-276.

Meixner J. 1928. Der genitalapparat der tricladen und seine beziehungen zu ihrer allgemeinen morphologie, philogenie, okologie und verbreitung. *Zeitschr. Morphol. Okol.* 11: 570–612.

Miller SA, Dykes DD, Polesky HF (1988) A simple salting out procedure for extracting DNA from human nucleated cells. Nucleic Acids Research 16(3): e1215. https://doi. org/10.1093/nar/16.3.1215

Miller MA, Pfeiffer W, Schwartz T. 2010. Creating the CIPRES science gateway for inference of large phylogenetic trees. In: Proceedings of the gateway computing

environments workshop (GCE) (pp. 1– 8). New Orleans, LA. https://doi.org/10.1109/ GCE.2010.5676129

Negrete L, Gira RD, Brusa F. 2019. Two new species of land planarians (Platyhelminthes, Tricladida, Geoplanidae) from protected areas in the southern extreme of the Paranaense Rainforest, Argentina. *Zoologischer Anzeiger* 279: 38-51.

Nguyen L-T, Schmidt HA, von Haeseler A, Minh BQ. 2015. IQ- TREE: A fast and effective stochastic algorithm for estimating maximum likelihood phylogenies. *Molecular Phylogenetics and Evolution* 32: 268– 274. https://doi.org/10.1093/molbe v/msu300

Oliveira U, Brescovit AD, Santos AJ. 2015. Delimiting Areas of Endemism through Kernel Interpolation. *PloS ONE*. 10(1): e0116673. https://doi.org/10.1371/journal.pone.0116673 PMID: 25611971

Pantin CFA. 1953. On the name of the ground fluke *Fasciola terrestris* O. F. Müller, on *Othelosoma symondsi* Gray, and on the genus Amblyplana von Graff. *Journal of the Linnean Society of London*. *Zoology* (Jena, Germany) 42: 207–218.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic Biology 61: 539–542. https://doi.org/10.1093/sysbio/sys029

Rossi I, Amaral SV, Ribeiro GG, Cauduro GP, Fick I, Valiati VH, Leal-Zanchet AM. 2016. Two new Geoplaninae species (Platyhelminthes: Continenticola) from Southern Brazil based on an integrative taxonomic approach. *Journal of Natural History* 50(13-14): 787-815.

Sluys R, Kawakatsu M, Riutort M, Baguñà J. 2009. A new higher classification of planarian flatworms (Platyhelminthes, Tricladida). *Journal of Natural History* 43: 29-30, 1763-1777, DOI: 10.1080/00222930902741669

Sluys R, Riutort M. 2018, Planarian diversity and phylogeny. In: Rink, J.C. (Ed.), Planarian Regeneration. Humana Press, New York, New York, pp. 1–56. https://doi.org/10.1007/978-1-4939-7802-1₁

Sluys R. 1989. Rampant Parallelism: An appraisal of the use of nonuniversal derived character states in phylogenetic reconstruction. *Systematic Zoology* 38(4): 350-370.

Sluys R. 2016. Invasion of the flatworms. *American Scientist* 104: 288-295.

Sluys R. 1999. Global diversity of land planarians (Platyhelminthes, Tricladida, Terricola): a new indicatortaxon in biodiversity and conservation studies. Biodivers Conserv. 8: 1663–1681.

Sluys R. 1995. Platyhelminthes as paleogeographical indicators. Hydrobiologia. 1995; 305: 49–53.

Stamatakis A (2006) RAxML-VI-HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. Bioinformatics 22(21): 2688–2690. https://doi. org/10.1093/bioinformatics/btl446

Szumik C, Cuezzo F, Goloboff PA, Chalup A. 2002. An optimality criterion to determine areas of endemism. *Systematic Biology*. 51: 806–816. https://doi.org/10.1080/10635150290102483 PMID: 12396592

Szumik C, Goloboff PA. 2004. Areas of endemism: an improved optimality criterion. *Systematic Biology*. 53: 968–977. https://doi.org/10.1080/10635150490888859 PMID: 15764564

Tyler S, Schilling S, Hooge M, Bush LF, comp. 2006. Turbellarian taxonomic database. Version 1.5. Available at http://turbellaria.umaine.edu.

Winsor L, Johns PM, Yeates GW. 1998. Introduction, and ecological and systematic background, to the Terricola (Tricladida). *Pedobiologia* 42: 389–404.

Winsor L, Johns PM, Yeates GW. Introduction, ecological and systematic background to the Terricola (Tricladida). Pedobiologia. 1998; 42: 389–404.

Winsor L. 1998. Aspect of taxonomy and functional histology in terrestrial flatworms (Tricladida: Terricola). *Pedobiologia* 42: 413-432.

Winsor L. 2003. Studies on the systematics and biogeography of terrestrial flatworms (Platyhelminthes: Tricladida: Terricola) of the Australian Region. James Cook University, Townsville. 439 pp (unpublished Ph.D. thesis).

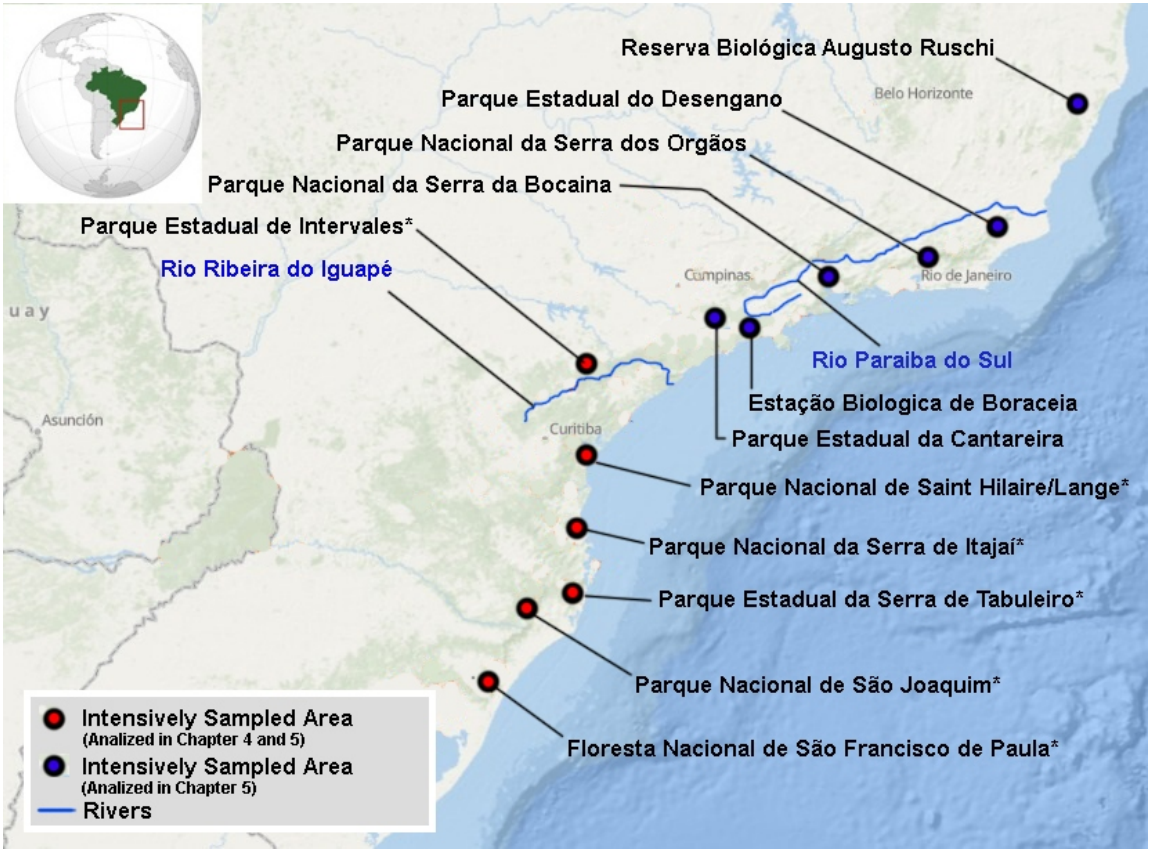


Fig. 1. Map of the 12 intensively sampled areas included in the study. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

Chapter 1

Taxonomic revision of four species of the Neotropical land planarian genera *Cratera* and *Geoplana* (Platyhelminthes, Tricladida) with a description of two new species and an emendation of *Cratera*.

This is the accepted version of the following article: **Lago-Barcia D**, Carbayo F. 2018. Taxonomic revision of four species of the Neotropical land planarian genera *Cratera* and *Geoplana* (Platyhelminthes, Tricladida) with a description of two new species and an emendation of *Cratera*. *Zootaxa* 4500 (4): 517–542 DOI 10.11646/zootaxa.4500.4.3.

Abstract

The Brazilian land planarians *Cratera crioula*, *C. joia*, *Geoplana hina*, and *G. taxiarcha* (Platyhelminthes, Tricladida, Geoplanidae) are revised taxonomically from type material and additional specimens. *Geoplana hina* sensu Carbayo et al. (2013) was found to be an undescribed species and therefore is described and named as *Cratera picuia* sp. n. A new species of the genus is also described and named as *Cratera arucuia* sp. n., *G. hina* and *G. taxiarcha* are transferred to *Cratera*. Most remarkable morphological feature of *Cratera* -a dilated terminal portion of the ejaculatory duct- is either absent, inconspicuous, or variable in *C. hina*, *C. joia*, *C. picuia* sp. n., and *C. arucuia* sp. n. Based on the monophyletic status of *Cratera* inferred elsewhere, an emendation of the genus is here proposed to encompass the morphological variation observed in the genus.

Key words: Continenticola, flatworms, morphology, taxonomy, anatomy, type material

Introduction

Land planarians, or Geoplanidae (Stimpson, 1857) (Platyhelminthes, Tricladida), mainly present a pantropical distribution. Most Neotropical species belong to the

Geoplaninae (Stimpson, 1857), a subfamily composed of 23 genera. Current systematics of the Geoplaninae is derived from a morphological approach and, more recently, molecular data has also contributed to its classification. Carbayo et al. (2013) studied the phylogenetic relationships of members of Geoplaninae. Some clades from the phylogenetic study gathered morphologically similar species, and the congruence between molecular-based clades and morphological similarity was the basis for a review of the classification of the Geoplaninae (Carbayo et al., 2013). As a result from that study, six new genera were proposed, including Cratera Carbayo et al., 2013, the focus group of the present work.

In Carbayo's et al. 2013 paper, *C. pseudovaginuloides* (Riester, 1938), *C. crioula* (Froehlich, 1955), *Geoplana hina* (Marcus, 1951), *C. tamoia* (Froehlich, 1955), and *C. yara* (Froehlich, 1955) and some undescribed species -*Cratera* sp. 1, sp. 2, sp. 4 and an immature individual- constituted a monophyletic group, formally named Cratera (Fig. 1). Later *Cratera* sp. 4 was formally described with the name *C. cuarassu* Carbayo & Almeida, 2015. At the moment of the proposal of the genus, *Cratera* encompassed these four described species, but *Geoplana hina* was considered incertae sedis and another species of *Geoplana*, *G. joia* (Froehlich, 1956) was transferred to *Cratera* even though this species lacks a distally dilated ejculatory duct.

Since then, ten new species of *Cratera* were proposed (Rossi et al., 2014, 2016; Carbayo & Almeida, 2015; Negrete & Brusa, 2016; Rossi & Leal-Zanchet, 2017).

Most remarkable morphological feature of the genus is that the terminal portion of the ejaculatory duct is dilated in some species (Carbayo et al., 2013). This morphological trait was formulated as "penis papilla protrusible, having distally a cavity continued from the ejaculatory duct" in the diagnosis. Some of the species in the genus do not present this trait, but no mention to the exceptions represented by those species was considered. This gap was noted by Negrete & Brusa (2016). From reviewing the literature, they also noted that (a) *C. crioula*, and *C. joia* do not present the cavity continued from the ejaculatory duct; (b) the prostatic vesicle of *C. joia* is intrabulbar, contrarily to the diagnosis of *Cratera*; (c) although *Geoplana hina* was nested within the molecular-based clade *Cratera*, Carbayo et al. (2013) did not transfer the species to the genus, and (d) that *C. joia* was transferred to *Cratera* even though it does not fit the diagnostic features of the genus (Negrete & Brusa, 2016). On the other side, we found

that *Geoplana taxiarcha* Marcus, 1951 presents an ‘ejaculatory duct that dilates immediately before its external orifice’ in one of the three type specimens, as stated by Marcus (1951, original in Portuguese).

It arises from this situation that *C. crioula*, *C. hina*, *C. joia* and *C. taxiarcha* are in need of a taxonomic revision. In this paper we redescribe these four species from the type material and additional specimens. We also address a detailed description of *Cratera* sp. 1 and of *G. hina* sensu Carbayo et al., 2013, above mentioned, and propose an emendation to the genus.

Materials and Methods

Type material of *C. crioula*, *C. hina*, *C. joia* and *C. taxiarcha* was deposited in the collection of the late Prof. Eudóxia Maria Froehlich, at the Departmento de Zoologia, Instituto de Biociências da Universidade de São Paulo (USP). This material is now deposited in the Museu de Zoologia da Universidade de São Paulo (MZUSP). Additional specimens of *C. crioula*, *C. hina* and *C. taxiarcha*, and representatives of *C. arucuia* sp. n. and *C. picuia* sp. n. were manually collected during daylight hours from under rocks and fallen logs and leaves. The flatworms were examined, photographed in vivo and then killed using boiling water. Each specimen was divided into two tissue portions for histology and DNA extraction, respectively.

The parts destined for histological studies were fixed in 10% formaldehyde, and subsequently preserved in 80% ethanol. The samples were progressively dehydrated in an ascending series of ethanol, cleared in clove oil and embedded in Paraplast® Tissue Embedding Medium. In the laboratory, photographs from the specimens cleared in clove oil were taken using a stereomicroscope with a camera attached. Tissue blocks were sectioned at 7 μm intervals using a retracting rotary microtome, affixed with albumin-glycerol (1:1) on glass slides placed on a hot plate and stained with the method Mallory-Heidenhain modified by Cason (1950). Reconstructions of the copulatory apparatus were carried out from the histological sections from the specimens and compared to descriptions in the literature. Figures of dorsal or sagittal views are orientated so that the anterior end of the body is to the left.

Abbreviations used in figures

(cg) cyanophil gland cells

(co) common glandular ovovitelline duct

(e) eye

(ej) ejaculatory duct

(ep) esophagus

(fa) female atrium

(fd) female genital duct

(g) gonopore

(gl) glands

(i) intestine

(lc) longitudinal cutaneous muscles

(m) muscle

(ma) male genital atrium

(ms) thin muscle fibre

(mo) mouth

(o) ovary

(ov) ovovitelline duct

(ph) pharyngeal pouch

(pb) penis bulb

(pp) penis papilla

(px) pharynx

(sb) subintestinal transverse muscles

(sd) sperm duct

(se) necks of secretory cells

(sg) shell glands

(sp) supraintestinal transverse muscles

(t) testis

(vi) vitellaria

(vn) ventral nerve plate

Results

Cratera crioula (Froehlich, 1955)

Synonymy
Geoplana crioula Froehlich, 1955

Material examined. All specimens collected in Parque Estadual da Cantareira, State of São Paulo, Brazil, (-23.41, -46.60). Holotype (MZUSP PL 2114): E. M. Froehlich & C. G. Froehlich, August 1952, sagittal sections of pharynx and copulatory apparatus on 7 slides (slides S809-S815; illustrated in Fig. 33 and 34 in Froehlich, 1955)). F2946 (MZUSP PL 423): F. Carbayo et al. coll., 26 October 2008, sagittal sections of pharynx and copulatory apparatus on 50 slides. F3709 (MZUSP PL 1078): F. Carbayo et al. coll., 19 April 2009, transverse sections of cephalic region on 18 slides; horizontal sections of portion behind cephalic region on 28 slides; transverse sections of pre-pharyngeal region on 8 slides; sagittal sections of pharynx and copulatory apparatus on 49 slides. F3712 (MZUSP PL 2116): F. Carbayo et al. coll., 19 April 2009, sagittal sections of pharynx and copulatory apparatus on 27 slides. F3715 (MZUSP PL 1079): F. Carbayo et al. coll., 19 April 2009, sagittal sections of pharynx and copulatory apparatus on 42 slides. F3744 (MZUSP PL 2117): F. Carbayo et al. coll., 20 April 2009, sagittal sections of copulatory apparatus on 9 slides.

Distribution. Only known from the type locality, Parque Estadual da Cantareira, State of São Paulo, Brazil.

Diagnosis. Species of *Cratera* with 40 mm in maximum length. Dorsum dark brownish, usually with a thin median cream-color stripe and a submarginal stripe on each side of the body with the same color. Dorsal eyes initiating in cephalic region. Pharynx bell-shaped. Proximal portion of prostatic vesicle bifurcated, extrabulbar, detached from penis bulb. Penis bulb extends 0.5 millimeters anteriorly to penis papilla. Ejaculatory duct may be distally widened. Dorsal insertion of penis papilla slightly anterior to the

ventral. Penis papilla projects into female atrium. Female:male atrial length ratio, 0.5-1. Common glandular duct present.

Description

We agree with Froehlich's (1955) description in most aspects. Herein we complement the description and make some observations on the ejaculatory duct.

External aspect. Body margins nearly parallel when crawling; anterior end rounded, posterior pointed. Dorsum convex, ventral side nearly flat. At rest and when contracted, the body is lanceolate (Fig. 2A-C). The largest preserved specimen was 60 mm in length and 5 mm in width (specimen F2946); specimen F3709 measured 39 mm long, and 6 mm wide. Dorsal surface with dark brownish black pigment spots, excepting a thin median stripe and a submarginal stripe on each side of the body, where the cream ground color of the body appears (Fig. 2A-B). These stripes may also be unconspicuous behind anterior extremity (Fig. 2C). The ventral side is cream-colored, passing into greyish in the anterior extremity (Fig. 2D).

Eyes monolobated, 35 µm in diameter, contouring cephalic region. They spread over dorsum from anterior extremity (Fig. 2E), backwards. At the level of the pharynx they extend on a lateral band, on each side of the body, with 1/3 of the body width. From that region towards the posterior extremity they spread on a band progressively narrower. Unconspicuous small halos around each eye present. Sensory pits 20 µm deep, contouring cephalic region and extending ventro-marginally backwards on a length equal to at least 20% of body length. Relative mouth:body length and relative gonopore:body length, 58% and 78%, respectively in holotype, and 72% and 85% in specimen F3709.

Internal morphology. Glandular margin present, constituted by erythrophil granular glands and xanthophil granular glands. Cutaneous musculature with the usual three layers present in the subfamily Geoplaninae: a thin subepithelial circular layer (2.5 µm thick) followed by a diagonal with decussate bundles (10 µm thick), and then a longitudinal layer (50 µm thick dorsally, 25 µm ventrally) arranged in bundles. Cutaneous musculature as thick as 14% of body height.

The three most common parenchymal muscle layers are also present, i.e., a weak dorsal layer of decussate diagonal fibers (20 µm thick), a very well developed supraintestinal layer of transverse fibers (80 µm thick), and a subintestinal layer (80 µm thick). Parenchymal longitudinal musculature absent. There are no subepidermic nor parenchymal muscle modifications in cephalic region.

Relative position mouth:pharyngeal pouch length, of 62%. Pharynx bell-shaped. Esophagus present, with 19% of pharynx length. Outer epithelium of the pharynx underlain by a thin layer (3 µm thick) of longitudinal muscle, followed by a thin layer of circular fibers (6 µm thick). Inner pharynx musculature consisting of a subepithelial layer (2 µm thick) of longitudinal musculature, followed by a circular layer (150 µm thick) with scattered longitudinal fibers interspersed and an ectalmost 10 µm thick layer of longitudinal fibers.

Testes arranged in a row of 2-3 testes on each side of the body. They extend from 2 mm behind the level of the ovaries (equal to 5% of the body length) to closely the root of the pharynx (equal to 60% of the body length) (specimen F3709). Lateral to the mid-region of the prostatic vesicle, sperm ducts curve medially to communicate with the two very short branches of the prostatic vesicle. Prostatic vesicle large and extrabulbar, detached from penis bulb. Anterior half of the unpaired section of this vesicle C-shaped, posterior half runs sinuously backwards, subsequently penetrates the penis bulb to continue as a straight ejaculatory duct. The ejaculatory duct traverses the central region of the penis papilla to open at its tip. The lumen of this duct is 20 µm in diameter, and widens 1.5 times distally in the holotype (Fig. 2F); widening of distal section of this duct not remarkable in specimen F3712; it passes from 15 µm to 20 µm distally. In specimen F3744 there is no widening at all.

Penis bulb well developed; extending anteriorly to penis papilla 0.5 mm. The prostatic vesicle is lined with a ciliated epithelium, and is pierced by glands producing erythrophil granules. This epithelium is surrounded by a circular muscle (15 µm thick). The penis papilla is conical, large and extends into the female atrium. This papilla is lined with a non-ciliated, cuboidal epithelium, and is underlain by a 25 µm thick circular muscle, followed by a 6 µm thick of longitudinal muscle. The ejaculatory duct is lined with a cuboidal ciliated epithelium, and is underlain by a circular muscle 10 µm thick. The male atrium is broad, not folded, and mostly occupied by the penis papilla

(Fig. 3A-B). The muscularis of the male atrium consists of a thin 10 µm thick circular muscle, followed by a thinner longitudinal muscle. There is no accumulation of cyanophil glands that pierce its roof.

Ovaries roughly rounded, 250 µm in diameter. They are located at a distance from anterior end equal to 23% of body length. Ovovitelline ducts arise from the dorso-lateral aspect of the ovaries. Behind the level of the gonopore, ovovitelline ducts ascend to communicate with each other above dorsal section of female atrium. Distal ascending section of ovovitelline ducts receives shell glands (Fig. 3B). Common ovovitelline duct horizontal; female genital duct is a projection of the postero-dorsal region of female atrium and is dorso-anteriorly oriented. The female atrium is an ample cavity continued with the male atrium; female:male atrial length, 1:1. Female atrium is lined with a 40 µm high epithelium with stratified aspect and internal gaps (Fig. 3A-B), and is underlain by a 5 µm thick circular muscle, followed by a 5 µm thick longitudinal muscle.

Remarks

In E. M. Froehlich's collection, there is a number of slides labeled only 'crioula'. However, full coincidence of the histological slides S809-S815 with drawings of copulatory apparatus and pharynx supported recognition of the holotype.

Original description makes no mention to the distal widening of the ejaculatory duct present in the holotype. This widening is relatively small and may not exist in some specimens.

Cratera hina (Marcus, 1951), comb. n.

Synonymy

Geoplana hina Marcus, 1951

Geoplana hina; Carbayo et al., 2013, non *Cratera hina* (Marcus, 1951)

Material examined. Reserva Biológica do Alto da Serra de Paranapiacaba, Santo André, State of São Paulo, (-23.77, -46.30). Holotype (MZUSP PL 2118). November 1950, transverse sections of pre-pharyngeal region on 2 slides (S431-S432); sagittal sections of pharynx on 2 slides (S433-S434); sagittal sections of copulatory apparatus on 3 slides

(S428-S430). F5682 (MZUSP PL 2119). F. Carbayo et al., coll. 21 December 2012, horizontal sections of anterior end on 9 slides; transverse sections of pre-pharyngeal region on 3 slides; horizontal sections of pharynx and copulatory apparatus on 10 slides. Note: Specimen MZUSP PL 1008, examined in Carbayo et al. (2013), is not conspecific (see Remarks on C. picuia sp. n.).

Our observations of the material examined are in agreement with Marcus' (1951) description. Here we complement the original description and made a reinterpretation of the ventral cavity of the female atrium.

Distribution. Only known from the type locality, Reserva Biológica do Alto da Serra de Paranapiacaba, Santo André, State of São Paulo, Brazil.

Diagnosis. Species of *Cratera* with 60 mm in maximum length. Dorsal coloration constituted of a median orange band and a lateral black band on each side. Dorsal and ventral epidermis ciliated. Dorsal eyes initiating in cephalic region. Penis bulb short, extending very little anteriorly to the penis papilla. Proximal portion of prostatic vesicle bifurcated, extrabulbar and attached from penis bulb. Ejaculatory duct not dilated distally. Muscle tube surrounding ejaculatory duct thick, with diameter equivalent to three times to that of the ejaculatory duct. Underlying muscularis of the penis papilla constituted by three layers, two circular and a longitudinal in between. Dorsal insertion of penis papilla slightly anterior to the ventral. Penis papilla projects into female atrium. Dorsal surface of the male atrium pierced by numerous glands. Common glandular duct absent.

Description

External aspect. Color of the dorsum constituted of a median orange band and a lateral black band, on each side of the body; anterior margin black (Fig. 3A). Eyes monolobulated. They spread from anterior tip to rear end of the body, and occupying the dorsal surface to the maximum extent of about 1/4-1/3 of the body width in mid body, on either side. Clear halos present around the eyes. Sensory pits are 15 µm deep. They are arranged in a single row and contour the anterior extremity. They extend backwards to at least a length equal to 31% of body length. The creeping sole is as wide as 90% of

the body width, provided with 5 µm long cilia at the pre-pharyngeal region. Relative mouth:body length and relative gonopore:body length, 68% and 80%, respectively in holotype, and 71% and 81% in specimen F5682. Dorsal epidermis provided with 2.5 µm long cilia.

Internal morphology. There is a glandular margin, which is composed of two types of cells secreting erythrophil and xanthophil granules, respectively. Cutaneous musculature with the usual three layers present in the subfamily Geoplaninae: a thin subepithelial circular layer (2.5 µm thick, dorsally and ventrally) followed by a diagonal with decussate bundles (10 µm thick dorsally, 22 µm ventrally), and then a longitudinal layer (45 µm thick dorsally, 55 µm ventrally) arranged in bundles. Cutaneous musculature as thick as 12% of body height.

The three most common parenchymal muscle layers are also present, i.e., a weak dorsal layer of decussate diagonal fibers (25 µm thick), a supraintestinal layer of transverse fibers (40 µm thick), and a subintestinal layer (40 µm thick). There are no subepidermic, nor parenchymal muscle modifications in the cephalic region.

Esophagus present, with 17% of pharynx length. Relative position mouth:pharyngeal pouch length, of 60%. Pharynx cylindrical. Outer epithelium of the pharynx underlain by a thin layer (3 µm thick) of longitudinal muscle, followed by a thin layer of circular fibers (8 µm thick). Inner pharynx musculature consisting of a subepithelial layer (2 µm thick) of longitudinal musculature, followed by a circular layer (100 µm thick) and an ectalmost 10 µm thick layer of longitudinal fibers.

Testes are arranged in a single row on each side of the body. They extend from 400 µm behind the level of the ovaries (equal to 29% of the body length, specimen F5682) to closely the root of the pharynx (equal to 68% of the body length). Shortly anterior to the penis bulb, sperm ducts curve medially to communicate with the two short branches of the prostatic vesicle. The unpaired section of the prostatic vesicle, attached to the penis bulb, runs dorsally, subsequently penetrates the penis bulb to continue as an ejaculatory duct. Penis bulb moderately developed, extending very little anterior to the penis papilla. The prostatic vesicle is lined with a ciliated epithelium, and is pierced by glands producing erythrophil granules. It is surrounded by a circular muscle layer (10 µm thick). This duct traverses the central region of the penis papilla to open at its tip; there is no dilation in the distal portion of the duct. The ejaculatory duct

is lined with a ciliated epithelium. This duct is 25 µm in diameter, and is surrounded by a conspicuous 30 µm thick circular muscle which becomes thinner distally (Fig. 4B). This muscle constitutes a tube with diameter equivalent to three times the diameter of the ejaculatory duct. The penis papilla is conical, horizontal, and is lined with a cuboidal, non-ciliated epithelium (Fig. 4B-D). Its underlying muscularis is compact; it consists of an 18 µm thick layer of circular fibers followed by a 5 µm thick of longitudinal fibers and an innermost 12 µm thick layer of circular fibers (Fig. 4B). The stroma of the penis papilla is traversed by numerous glands discharging erythrophil granules through the epithelium of the papilla; they pierce its dorsal epithelium at highest density. The muscularis of the male atrium consists of a 10 µm thick circular muscle, followed in the distal half of the atrium by some longitudinal fibers. There is a distinct dorsal surface of the male atrium pierced by numerous glands producing pinkish granules (Fig. 4C, E).

Ovaries 500 µm long and 200 µm wide (specimen F5682). They are located at a distance from anterior end equal to 31% of body length. The ovovitelline ducts arise from the dorso-lateral aspect of the ovaries. Shell glands pierce distal section of these ducts only (Fig. 4E). Thus, there is no common glandular ovovitelline duct. The female genital duct projects from postero-dorsal portion of female atrium, and is lined with a non ciliated epithelium. This epithelium is underlain by a 10 µm thick circular muscle layer. The female atrium is a cavity with 1-2 lateral folds; female:male atrial length, 1:1.5. This atrium is lined with a 25 µm high epithelium, which is underlain by a 20 µm thick muscle layer of circular and longitudinal fibers (Fig. 4D); circular muscle fibers are predominant in posterior section of female atrium.

Remarks

Prof. Eudóxia M. Froehlich kept in her office the histological slides of most land planarians studied by Marcus. Histological slides in her collection include more than one specimen labeled only “hina”. Marcus presented diagrammatic reconstructions of the pharynx and the copulatory apparatus of the holotype (Figs. 259-264 in Marcus, 1951). These reconstructions fully match the organs on the histological sections of what we consequently consider to be the holotype.

Marcus (1951) described the distal portion of the penis papilla as housed in a ventral pouch of the female atrium. Our interpretation of parasagittal sections of the two specimens is that the presumed pouch is actually part of the single space constituting the female atrium which is partially occluded by its own lateral fold. Marcus also distinguished a short female genital duct -which is lined with ciliated epithelium-, from a dorsal diverticulum of the female atrium -lined with a nonciliated epithelium, after Marcus. However, we were unable to make this distinction since both epithelia are non ciliated.

Carbayo et al. (2013) included the specimen MZUSP PL 1008 in their molecular analyses. They identified this specimen as *Geoplana hin*a Marcus, 1951. Although very alike, the external aspect and the copulatory apparatus of this specimen do not fully match diagnosis of *C. hina*. See below the section Remarks on *Cratera picuia* sp. n.

Cratera joia (Froehlich, 1956)

Synonymy
Geoplana joia Froehlich, 1956

Material examined. Syntypes. Parque Estadual Serra do Mar (between Curitiba and Paranaguá), State of Paraná, Brazil, July 1953, Froehlich and Froehlich, coll. Syntype A (MZUSP PL 2121): sagittal sections of copulatory apparatus on 3 slides (S444-S446). Syntype B (MZUSP PL 2122): sagittal of copulatory apparatus on 4 slides (S447-S450). Syntype A or B: transverse sections of pre-pharyngeal region on 2 slides (S440-S441); sagittal sections of pharynx on 2 slides (S442-S443). Syntype C (laboratory number: F7239; MZUSP PL 2120): transverse sections of cephalic region on 13 slides; horizontal sections of ovaries region on 5 slides; transverse sections of pre-pharyngeal region on 13 slides; sagittal sections of pharynx and copulatory apparatus on 15 slides.

Distribution. Only known from the type locality, Parque Estadual da Serra do Mar, State of São Paulo, Brazil.

Diagnosis. Species of *Cratera* with 40 mm in maximum length. Anterior tip, ventrally and dorsally, rust colored, same as a median and a pair of marginal lines. Rest of dorsum dark. Epidermis ciliated dorsally and ventrally. Eyes over entire dorsum. Sensory pits pear-shaped. Glandular margin unsharpened. Proximal portion of prostatic vesicle bifurcated, extrabulbar, and attached to penis bulb. Penis bulb extends 0.6 millimeters anteriorly to penis papilla. Ejaculatory duct may be slightly dilated distally. Dorsal insertion of penis papilla slightly anterior to the ventral. Penis papilla projects into female atrium. Distal dorsal section of penis papilla lined with an epithelium higher and sinuous; this epithelium pierced by numerous cyanophil glands. Common glandular duct present.

Description

External aspect. Preserved animals up to 40 mm long, and 5 mm wide. Body margins nearly parallel; anterior and posterior end pointed (Fig. 5A). Dorsum slightly convex. After original description, eyes spread over entire dorsal surface. Sensory pits are invaginations 50 μm deep; this invagination is slightly different from the straight shape in most geoplaninids, since it widens slightly at half its depth (Fig. 5B). Sensory pits are arranged in a single row. A ~10 μm long section of anterior apex of the body was lost; it is assumed sensory pits contour anterior end. Behind, sensory pits extend backwards to at least a length equal to 35% of body length. Relative mouth:body length, 70% and relative gonopore:body length, 80%, in syntype C.

Internal morphology. Creeping sole occupies 90% ventral body width. Externally to the creeping sole, there is a 200 μm wide band of nonciliated epidermis; remaining epidermis ciliated, even dorsally (Fig. 5B). Erythrophil glands producing erythrophil granules pierce dorsal epidermis. A second type of gland cell discharges its granules through the dorsal epidermis; these granules stained brownish black in syntypes A and B; and orangish in syntype C. The two types of glands present a progressive increase in number from the mid region to the body margins, where suddenly they cease, so the glandular margin is unsharpened. Ventral epidermis pierced by two types of glands producing erythrophil and cyanophil granules, respectively.

Cutaneous musculature with the usual three layers present in the subfamily Geoplaninae: subepithelial circular (one-fiber thick), diagonal with decussate bundles (7

μm thick) and an innermost longitudinal layer (25 μm thick), the latter is arranged in bundles. Cutaneous musculature as thick as 8% of body height. Parenchymal musculature composed of three muscular layers: a weak dorsal layer with diagonal decussate fibers (10-12 μm thick) and a supraintestinal (25 μm thick) loose layers and a subintestinal transverse layer (40 μm thick). Ventral nerve plate present.

Relative position mouth:pharyngeal pouch length, of 73%. (Fig. 5C). Pharynx cylindrical, with its dorsal insertion slightly placed backwards. Esophagus present, with 30% of pharynx length. Outer pharyngeal musculature consisting of a subepithelial layer (3 μm thick) of longitudinal muscle, followed by a layer (5 μm thick) of circular fibers. Inner pharynx musculature consisting of a subepithelial layer (60 μm thick) of circular musculature with some longitudinal fibers interspersed.

Testes located between supraintestinal parenchymal muscle layer and intestine. Testes are arranged in single-to-double row on each side of the body. They extend from the level of the ovaries (equal to 35% of the body length in syntype C) to closely the root of the pharynx (equal to 61% of the body length in syntype C). Penis bulb consisting of packed muscle fibers variously oriented. This bulb extends from 0.6 millimeters anterior to penis papilla to envelope the anterior half of the male atrium approximately. Sperm ducts run laterally to open into short paired branches of the extra-bulbar portion of the prostatic vesicle (Fig. 5D). Extra-bulbar portion of the prostatic vesicle is C-shaped in lateral view and is attached to the penis bulb. Subsequently, the prostatic vesicle penetrates the anterior section of the penis bulb to continue as a sinuouse tube until it continues as the ejaculatory duct inside the penis papilla. The prostatic vesicle is lined by a columnar, ciliated epithelium. This epithelium is surrounded by a 15 μm thick circular muscle. Glands producing very weakly stained reddish (syntypes A and B) or bluish (syntype C) secretion open into prostatic vesicle. Ejaculatory duct runs straight through the penis papilla. The ejaculatory duct is lined with a cuboidal, ciliated epithelium. It is surrounded by a 5 μm thick circular muscle. The lumen of ejaculatory duct is 12.5 μm in diameter proximally, subsequently it narrows to 7.5 μm and it widens slightly to 17.5 μm distally before opening at the tip of the penis papilla (syntype A, Fig. 5F). There is no distal widening of the ejaculatory duct in syntypes B and C.

Penis papilla relatively long, cylindrical, pointed distally, and with its dorsal insertion slightly anterior than the ventral. It exceeds the gonopore level to occupy anterior half of the female atrium. This papilla is lined with an epithelium which is columnar anteriorly, and cuboidal distally and is underlain by a circular muscle (5 μm thick), followed by a longitudinal muscle (12 μm thick). Most epithelium of penis papilla is pierced by erythrophil glands. These glands are absent in distal dorsal section of the penis papilla, which in turn is pierced by numerous glands producing fine cyanophil granules (Fig. 5F). The lining epithelium of this section of the penis papilla is sinuous and two times higher; underlying muscle is also thicker. The male atrium is not folded. It is lined with a cuboidal, non-ciliated epithelium, and is underlain by an 8 μm thick circular muscle.

The ovaries are rounded, 300 μm in diameter (syntype C). They are located at a distance from anterior end equal to 35% of body length. The ovovitelline ducts arise from the dorso-lateral aspect of the ovaries. Ovovitelline ducts 50 μm in diameter along most of its length. They run laterally, rise laterally to the female atrium, and join to form the common glandular ovovitelline duct above female atrium (Figs. 6A, B). The distal section of the ovovitelline ducts widens to a thickness of 80 μm in syntype A. Numerous shell glands discharge into final portion of ovovitelline ducts. The common glandular ovovitelline duct runs posteriorly to open to the female genital duct. The female genital duct is an anteriorly directed projection from the posterior region of female atrium.

Female atrium is ample, and not folded. It is not separated from the male atrium; the female:male atrial length is 2:1.5. This female atrium is lined with a nonciliated epithelium, which is 38 μm high posteriorly, and 20 μm high anteriorly. This epithelium has a multilayered aspect and presents scattered gaps containing fine erythrophil granules. The female lining epithelium is surrounded by a thin longitudinal muscle with circular fibers intermingled ectally.

Remarks

Froehlich did not designate explicitly holotype and paratypes among the eight specimens he mentioned in the original description. He sectioned two specimens, the ones we here named syntype A and B, respectively. A diagrammatic representation of

the copulatory apparatus of syntype A was illustrated in the original description of the species (Fig. 20 in Froehlich, 1956). A diagrammatic representation of the pharynx of either syntype A or B was illustrated in the original description of the species (Fig. 21 in Froehlich, 1956). We sectioned a third type specimen, here named syntype C, from Eudóxia's wet collection.

We noted some minor differences with respect to original description, namely (a) the mouth is not placed at the end of the pharyngeal pouch, but in its second third; (b) proximal portion of the prostatic vesicle is not intrabulbar but extrabulbar, albeit attached to it; and (c) Froehlich describes erythrophil glands discharging through the dorsal surface of the male atrium. However, we could not distinguish muscle tissue from any other structure such as glands surrounding dorsal surface of the male atrium in syntypes A and B. In syntype C, the dorsal surface of the male atrium is missing these glands as well.

Cratera taxiarcha (Marcus, 1951)

Synonymy
Geoplana taxiarcha Marcus, 1951

Material examined. Holotype (MZUSP PL 2135). Horto Florestal, State of São Paulo, Brazil, (-23.46, -46.63) (coordinates provided by the authors of the present study). Unknown coll. between August and November, 1950, sagittal sections of copulatory apparatus on 2 slides (S247-S248). F3518 (MZUSP PL 2136): Parque Estadual da Serra da Cantareira, São Paulo, State of São Paulo. Brazil, (-23.43, -46.63). F. Carbayo et al. coll., 26 March 2009, transverse sections of cephalic region on 28 slides; transverse sections of ovaries region on 25 slides; horizontal sections of region behind ovaries on 12 slides; transverse sections of pre-pharyngeal region on 26 slides; sagittal sections of pharynx on 28 slides; sagittal sections of copulatory apparatus on 23 slides.

Distribution. Horto Florestal and Parque Estadual da Cantareira, São Paulo, State of São Paulo, Brazil.

Diagnosis. Species of *Cratera* with 70 mm in maximum length. Dorsal coloration constituted of a white median line, two paramedian black lines and two marginal yellow lines. Dorsal eyes initiating in cephalic region. Proximal portion of prostatic vesicle bifurcated, extrabulbar, detached from penis bulb. Penis bulb well developed, extending 0.5 millimeters anteriorly to penis papilla. Diameter of muscular cylinder surrounding ejaculatory duct strong, two times the diameter of this duct. Dorsal portion of male atrium pierced by numerous cyanophil glands. Female:male atrial length ratio, 0.5-1. Common glandular ovovitelline duct absent.

Description

External aspect. Body wide, slightly lanceolate, with anterior tip rounded and posterior tip pointed. Size of preserved animal (F3518) is 52 mm long and 6 mm wide. Dorsum slightly convex, ventral side flat. Dorsal coloration consists of a median white line with scattered black spots, flanked by two paramedian black lines with irregular margins, which are constituted by a high concentration of black spots. Laterally to paramedian black lines, two yellow marginal lines, having black spots scattered along its length, especially in the anterior third of the body, where the spots create a thin marginal black line (Fig. 7A). Ventral surface whitish.

Sensory pits are 30 µm deep. They are arranged in a single row contouring the anterior end and extending backwards to at least a length equal to 27% of body length. Relative mouth:body length, 71%; relative gonopore:body length, 87% (specimen F3518).

Internal morphology. Creeping sole occupies entire body width. Glandular margin relatively less developed, constituted by xanthophil glands. Cutaneous musculature with the usual three layers present in Geoplaninae: subepithelial circular (5 µm thick), diagonal with decussate bundles (10 µm thick) and an innermost longitudinal layer (50 µm thick), the latter more conspicuous and arranged in bundles. Cutaneous musculature as thick as 7% of body height. Parenchymal musculature composed of three muscular layers: a dorsal layer with diagonal decussate fibers (15 µm thick in paratype F3518), a

supraintestinal transverse layer (40 μm thick), and a subintestinal transverse layer (50 μm thick). Ventral nerve plate present.

Relative position mouth:pharyngeal pouch length, of 69%. Pharynx cylindrical (Fig. 7B), with dorsal insertion slightly posteriorly to the ventral one; esophagus present, with 27% of pharynx length. The outer epithelium of the pharynx is underlain by a thin layer (5 μm thick) of circular muscle, followed by a thin layer of longitudinal fibers (8 μm thick), this layer only present in the proximal section of the pharynx. Inner pharyngeal epithelium underlain by a thick circular muscle (40-120 μm thick), followed by a longitudinal muscle (15 μm thick).

Testes dorsally located between supraintestinal parenchymal muscle layer and intestine. They extend from the level of the ovaries (equal to 25% of the body length in specimen F3518) to closely the root of the pharynx (equal to 61% of the body length in specimen F3518). Sperm ducts run laterally and, anteriorly to the penis bulb, subsequently bend medially to open into the short branches of the proximal portion of the prostatic vesicle. The proximal two thirds of the prostatic vesicle, extrabulbar, is C-shaped in lateral view. The prostatic vesicle penetrates dorso-anterior aspect of penis bulb, subsequently running ventro-posteriorly to communicate with the ejaculatory duct within the penis papilla. The entire prostatic vesicle is lined by a cuboidal-to-columnar ciliated epithelium and is pierced by glands producing fine erythrophil granules. This epithelium is surrounded by a 20 μm thick circular muscle layer. Penis bulb well developed, extending 0.5 mm anterior to the penis papilla. Ejaculatory duct crosses the center of the penis papilla. This duct is 50 μm in diameter proximally, and 25 μm distally. The ejaculatory duct opens to male atrium through a widening 150 μm in diameter (Fig. 7C-D). The ejaculatory duct is lined by a cuboidal ciliated epithelium and is underlain by a circular muscle 10 μm thick. The penis papilla is conical, horizontally located, with dorsal and ventral insertions at the same transverse plane and approximately as long as the male atrium (Fig. 8A and 9A, B). The papilla is lined with a cuboidal epithelium, which is underlain by a 10 μm thick circular muscle, followed by a 5 μm thick longitudinal muscle. The male atrium is broad, not folded, and mostly occupied by the penis papilla. Dorsal portion of male atrium pierced by abundant cyanophil glands. The muscularis of the male atrium consists of a thin 10 μm thick circular muscle, followed by a thinner longitudinal muscle.

Ovaries ovoid, 300 μm in diameter, placed above the ventral nerve plate, and at a distance from anterior end equal to 25% of body length. Ovovitelline ducts emerge from dorso-lateral aspect of ovaries. Laterally to the female atrium, ovovitelline ducts ascend to communicate with each other above dorsal section of female atrium. Distal ascending section of ovovitelline ducts receive shell glands. No common glandular ovovitelline duct present. Female genital duct as an anteriorly oriented projection from postero-dorsal region of female atrium.

The female atrium is a cavity partially narrowed by a lateral fold. It is continued with the male atrium; female:male atrial length, 2:3.5. The female atrium is lined by an epithelium with stratified appearance and internal gaps, and is underlain by a 5 μm thick circular muscle, followed by a 5 μm thick longitudinal muscle.

Common muscle coat composed of scattered fibers, and is more apparent around female atrium.

Remarks

The type material consisted of five adult specimens and an immature one, collected in Horto Florestal, São Paulo, State of São Paulo and Mogi das Cruzes, State of São Paulo, in 1950. Marcus described a very variable chromatic pattern of the specimens: “The species color varies. The venter may be white or greish-yellowish. The ground color is white, though the dorsum may be completely black. Other individuals present a median white line and two clear yellow lateral lines (Fig. 310). These lines may be different or allusive; in the last instance, the median line appears only in the anterior region (Fig. 261). In the clearer worms (Fig. 259), the white and yellow lines turn into wide bands, restricting the black pigment to two paramedian bands, the body margins and spots on the yellow zones, being more numerous in the posterior region” (Marcus, 1951, p. 101; original in Portuguese).

It is striking that Marcus considered animals with so different color patterns as conspecific. Based on our experience, such great variation of the chromatic pattern of the body most likely reflects non-conspecificity.

Later, Marcus seems to have noticed that he misidentified the species and that it was a junior synonym of *Geoplana ferussaci* Graff, 1899 (E. M. Froehlich, pers. comm.). However, he did not address this issue. Jokingly, he simply recorded his

suposedly misidentification by glueing a newspaper clipping on an illustration of hatchlings of ‘taxiarcha’ and ‘ferussaci’ types, hatched in the laboratory in 1951 as a metaphor: the clipping briefly reports the wreck of a Greek ship called ‘Taxiarchis’ on the English coast (Fig. 10) (E. M. Froehlich, pers. comm.).

We believe that Marcus dealt with representatives of *G. taxiarcha* and at least a second species, possibly *G. ferussaci*. The taxonomic problem here presented is to pair one of the chromatic patterns of the body described by Marcus with the internal organs described and illustrated by him. Marcus’s notebooks, retained by Eudóxia, did not help solve this enigma. There are four entries for *G. taxiarcha* for the year 1950 in a notebook. None of these entries refers to a specimen with a color pattern like that of Fig. 310.

Even more striking is that only one (on slides S247-S248) of the three copulatory apparatuses he sectioned has survived in Eudóxia’s collection. In this collection, there are no additional slides of this species collected in 1950. Also there are no specimens from the Horto Florestal or Mogi collected in 1950 in the wet collection of E. M. Froehlich.

We believe that Marcus’ Fig. 310 of the dorsal color pattern is from a specimen conspecific with the one -if not the same specimen- whose copulatory apparatus is on the histological slides S247-S248. Our belief is based on that (a) our specimen F3518 presents a dorsal color pattern and a copulatory apparatus fully comparable with Marcus’s Fig. 310 and with the copulatory apparatus on slides S247-S248, respectively; and (b) specimen F3518 was collected in the Horto Florestal, as the holotype was.

Each of the slides S247-S248 bears a label handwritten by Marcus reading “G. taxiarcha”. The same handwriting is on the labels of slides S246 and S257, including transverse sections of the pre-pharyngeal region and sagittal sections of the pharynx, respectively. However, none of the two pharynges drawn by Marcus in his paper was based on the slide S257. We are unable to confirm that these sections are part of the specimen sectioned on slides S247-S248. Hence, herein we suggest as holotype of C. taxiarcha only the body parts mentioned in Material examined.

The holotype and specimen F3518 present the ejaculatory duct with distal widening.

Cratera picuia sp. n.

Synonymy

Geoplana hina; Carbayo et al., 2013, non *Cratera hina* (Marcus, 1951)

Type material. Holotype MZUSP PL 1008 (field number F1613): Parque Nacional Saint-Hilaire/Lange, Matinhos, State of Paraná, Brazil (25.76437, -48.62266). F. Carbayo et al. coll., 10 January 2008, transverse sections of cephalic region on 11 slides; horizontal sections of ovaries region on 10 slides; transverse sections of prepharyngeal region on 9 slides; sagittal sections of pharynx and copulatory apparatus on 7 slides.

Distribution. Only known from the type locality, Parque Nacional Saint-Hilaire/Lange, Matinhos/PR, Brazil.

Etymology. The name picuia is a free composition of the Tupi (indigenous Brazilian language) words py (meaning inside) and cuia (meaning gourd, the dried shell of a cucurbit plant (Tibiriçá, 1984)). It refers to the uncommon, innner location of the prostatic vesicle inside the penis bulb.

Diagnosis. Species of *Cratera* with dorsal color constituted by a pair of pearl orange paramedian bands separated by a median ivory-colored band, and paired oyster white marginal bands, each one longitudinally divided in half by black grey spots. Prostatic vesicle canalicular, located inside penis bulb. Ejaculatory duct not dilated distally.

Description

External aspect. Live holotype with elongated body, with margins approximately parallel; anterior extremity of the body damaged during handling and lost ca. 0.5mm; posterior end damaged, but pointed. Dorsum convex, ventral side slightly convex. Dorsal color constituted by a pair of pearl orange paramedian bands (1.5/7th) separated by a median ivory-colored band (1/7th of body width), and paired oyster white marginal

bands (1/7th) each one longitudinally divided in half by black grey spots which become more abundant posteriorly so as to create an irregular longitudinal stripe (Fig. 11A). Ventral body surface, white. After fixation, body became cream with the exception of the black grey lines, which became brown grey. Preserved holotype 28 mm long, and 3 mm wide.

Eyes monolobulated, 50 μm in diameter. A ~0.5 mm long section of anterior apex of the body was lost; it is assumed they contour cephalic region. They spread over dorsum from anterior extremity, backwards. At the level of the pharynx they extend on a lateral band, on each side of the body, with 1/3 of the body width. From that region towards the posterior extremity they spread on a band progressively narrower. On black-brownish bands, small halos around each eye. Sensory pits are 30 μm deep invaginations arranged in a single row. It is assumed sensory pits contour anterior end. Behind, sensory pits extend backwards to at least a length equal to 36% of body length. Relative mouth:body length, 68% and relative gonopore:body length, 75%.

Internal morphology. Creeping sole occupies 88% ventral body width. Rhabditogen cells and erythrophil glands producing erythrophil fine granules pierce dorsal epidermis. Glandular margin constituted by two types of glands producing granules, eruthrophil and xanthophil, respectively. Ventral epidermis pierced by glands producing erythrophil granules.

Cutaneous musculature with the usual three layers present in the subfamily Geoplaninae: subepithelial circular (one-fiber thick), diagonal with decussate bundles (5 μm thick) and an innermost longitudinal layer (27 μm thick dorsally, 47 μm ventrally), the latter is arranged in bundles. Cutaneous musculature as thick as 9% of body height. Parenchymal musculature composed of three muscular layers: a dorsal layer with diagonal decussate fibers (20-25 μm thick), a supraintestinal (70 μm thick) loose layers and a subintestinal transverse layer (50 μm thick). Ventral nerve plate present.

Relative position mouth:pharyngeal pouch length, of 72% (Fig. 11B). Pharynx cylindrical, with its dorsal insertion placed backwards. Esophagus present, with 30% of pharynx length.

Close to the insertions of the pharynx, outer epithelium of the pharynx underlain by a thin layer (3 μm thick) of longitudinal muscle, followed by a thin layer of circular fibers (5 μm thick). Under epithelium of the distal section of the pharynx, the

longitudinal layer seems to be absent. Inner pharynx musculature consisting of a subepithelial layer (2 µm thick) of longitudinal musculature, followed by a circular layer (80 um thick) and an ectalmost 10 um thick layer of longitudinal fibers.

Testes dorsally located between intestinal branches. Testes are arranged in single-to-double row on each side of the body. They extend from 0.5 mm behind the level of the ovaries (equal to 30% of the body length) to 0.6 mm before the root of the pharynx (equal to 59% of the body length). Penis bulb consisting of packed muscle fibers variously oriented. This bulb extends from 0.3 millimeters anterior to penis papilla to envelope the anterior 0.25 mm of the male atrium. In their distal section, sperm ducts run medially to join below the level of the ventral insertion of the penis papilla (Fig. 11C), and subsequently continuing with the intrabulbar prostatic vesicle (Figs. 11D and 12A). The prostatic vesicle is canalicular, with proximal portion running anteriorly, and distal, shorter portion running posteriorly. Prostatic vesicle lined by a columnar, ciliated epithelium, which is surrounded by a 10 µm thick circular muscle. Glands producing intense erythrophil granules open into prostatic vesicle. The anteriormost portion of the ejaculatory duct is out of the penis papilla and is slightly sinuous. Most of the ejaculatory duct runs straight through the ventral portion of the penis papilla. The ejaculatory duct is lined with a cuboidal, ciliated epithelium. It is surrounded by a 15 µm thick circular muscle. The lumen of ejaculatory duct is 10 µm in diameter proximally; very gradually it narrows to 5 µm distally before opening at the tip of the penis papilla (Fig. 12B). There is no distal widening of the ejaculatory duct. Anterior 3/4th of this duct is pierced by very numerous glands producing erythrophil granules.

Penis papilla relatively conical, with its dorsal insertion slightly anterior than the ventral. It exceeds the gonopore level to occupy anterior half of the female atrium. Anteriorly, this papilla is lined with a columnar epithelium; gradually, this epithelium passes to squamous. Penis papilla epithelium is underlain by a circular muscle (18 µm thick), followed by a longitudinal muscle (4 µm thick). Most epithelium of penis papilla is pierced by glands producing xanthophil granules, but they are most abundant along distal half. Glands producing cyanophil granuels are scarce and restricted to the proximal, dorsal half of the epithelium. Male atrium not folded. It is lined with a cuboidal, non-ciliated epithelium, and is underlain by an 5-10 µm thick circular muscle

followed by a 5 um thick longitudinal muscle. Roof of male atrium pierced by a large mass of glands producing cyanophil granules.

The ovaries are ovoid, 400 µm long and 200 µm wide. They are located at a distance from anterior end equal to 28% of body length. The ovovitelline ducts arise from the dorso-lateral aspect of the ovaries. Ovovitelline ducts rise laterally to the female atrium, and join to form the very short common glandular ovovitelline duct (50 µm) above female atrium. Numerous shell glands discharge into final portion of ovovitelline ducts. The common glandular ovovitelline duct joins the long female genital duct (400 µm) (Fig. 12C). This duct is an anteriorly directed projection from the postero-dorsal region of female atrium. It is lined with a columnar, ciliated epithelium which is pierced by glands producing cyanophil granules. The glands piercing this epithelium are scarce but their bodies are abundant surrounding the epithelium.

Female atrium is ample, and not separated from the male atrium. A dorso-lateral fold narrows the lumen of the female atrium. Female:male atrial length is 8.5:10. This female atrium is lined with a nonciliated, columnar epithelium, which is 30 µm high. The female lining epithelium is surrounded by a 10-15 um thick muscle layer of longitudinal and circular fibers intermingled. This epithelium is pierced by two types of glands, one producing eryhtrophil granules, another producing cyanophil granules.

Remarks

This species was confounded with *Cratera hina* (Marcus, 1951) by Carbayo et al. (2013). The chromatic pattern of the dorsum of *C. picuia* sp. n. resembles that of *C. hina* but is not identical. Two circumstances led Carbayo et al. (2013) to misidentify the specimen (FC, pers. obs.): (a) the fact that intraspecific variation in the dorsal color pattern is not rare in geoplaninids [e.g. *Cephaloflexa bergi* (Graff, 1899), *Obama josefi* (Carbayo & Leal-Zanchet, 2001), *O. nungara* Carbayo et al., 2016]; and (b) the close resemblance of the shape of the internal organs of the new species, even the location of the prostatic vesicle, with that of the original description of *C. hina*. However, as shown above, in *C. hina* the prostatic vesicle is extrabulbar, whereas in *C. picuia* sp. n. the prostatic vesicle is intrabulbar. This latter trait is unique in *Cratera* and differentiates readily *C. picuia* sp. n. from all its congeners.

Cratera arucuia sp. n.

Synonymy

Geoplana sp. 2; Carbayo et al., 2013

Cratera sp. 2; Carbayo et al., 2013

Type material. Parque Estadual de Intevales, Ribeirão Grande, State of São Paulo, Brazil, (-24.2693, -48.4054) Holotype F2783 (MZUSP PL 1048): F. Carbayo et al. coll., 29 July 2008, sagittal sections of region behind ovaries on 13 slides and horizontal sections on 5 slides; transverse sections of pre-pharyngeal region on 7 slides; sagittal sections of pharynx and copulatory apparatus on 14 slides. Paratype F2784 (MZUSP PL 2112): F. Carbayo et al. coll., 29 July 2008, sagittal sections of copulatory apparatus and pharynx on 12 slides. Paratype F2696 (MZUSP PL 2110): F. Carbayo et al. coll., 25 July 2008, sagittal sections of copulatory apparatus on 19 slides. Paratype F2724 (MZUSP PL 2111): F. Carbayo et al. coll., 26 July 2008, transverse sections of cephalic region on 5 slides; sagittal sections of ovaries region on 4 slides; sagittal sections of region behind ovaries on 9 slides; sagittal sections of pre-pharyngeal region on 3 slides; sagittal sections of copulatory apparatus on 8 slides. Paratype F3094 (MZUSP PL 2113): F. Carbayo et al. coll., 12 December 2008, transverse sections of cephalic region on 8 slides; sagittal sections of ovaries region on 20 slides.

Distribution. Only known from the type locality, Parque Estadual de Intevales, Ribeirão Grande, State of São Paulo, Brazil.

Etymology. The name arucuia is a free composition of the Tupi (indigenous Brazilian language) words aru (meaning back, opposite side) and cuia (meaning gourd, the dried shell of a cucurbit plant (Tibiriçá, 1984)). It refers to the uncommon, dorsal location of the gourd or ovoid-like prostatic vesicle.

Diagnosis. Species of *Cratera* with dorsal coloration constituted by an orange median irregular stripe that can vary in size, lateral gray or black stripes and a gray marginal

stripe on a whitish cream ground color. Dorsal eyes initiating in cephalic region. Pharynx bell-shaped. Proximal section of prostatic vesicle ovoid, extrabulbar and positioned dorsally above the penis bulb. Penis bulb strongly developed, extending 1.8 mm anteriorly to the penis. Ejaculatory duct not dilated distally. Very thick circular muscle surrounding ejaculatory duct, equivalent to 4 times the diameter of this duct in its proximal region, and 2 times the diameter in its distal region. Penis papilla projects into female atrium. Female:male atrial length ratio, 1.4. Common glandular duct present.

Description

External aspect. Preserved animals up to 42.5 mm long, and 3 mm wide (holotype). Body margins nearly parallel; anterior end rounded, posterior pointed. Dorsum strongly convex, ventral side slightly convex; body sides thin. Dorsal ground color whitish cream. The median region presents a median stripe of irregular margins and variable width (8-30% of body width), constituted of orange small spots. This median stripe is absent on a variable portion of the anterior end (Fig. 13A, B), ranging from 1/10 to 3/4 of body length. An interval of ground color may separate this median line from dark gray or black lateral stripes, the external half of which is mottled with clear halos encircling eyes. These lateral stripes may vary in width (12%-32% of body width) (Fig. 13C). External to the lateral stripes and separated from them by an interval of ground color (17% of body width), is a marginal stripe of gray (12% of body width), with fading inner margin. These marginal stripes are also mottled with clear halos encircling eyes. Ventral surface whitish.

Eyes are monolobulated, spread from anterior tip (Fig. 13D) to rear end of the body, and are distributed over dorsal surface to the maximum extent of about 37% of the body width in mid body, on either side. Towards the rear end, they become scarcer and are progressively distributed over a narrower band. Sensory pits as simple invaginations 30 μm deep, located ventro-marginally in a single row from very anterior tip to, at least the level of the ovaries (equal to 34% of body length). Relative mouth:body length and relative gonopore:body length variable depending on length of animals (in holotype and paratypes F3094, F2724 and F2696 these values are 62%, 66%, 70%, 81% for mouth; and 63%, 76%, 57%, 86% for gonopore, respectively). This

pattern means that larger animals present mouth and gonopore in a relatively more anterior location.

Internal morphology. Creeping sole occupies 94% body width. Glandular margin present, composed of amorphous intense erythrophil glands, xanthophil glands and erythrophil granules, respectively. Cutaneous musculature with the usual three layers present in Geoplaninae: subepithelial circular (one fiber thick), diagonal with decussate bundles (10 μm thick) and an innermost longitudinal layer (50 μm thick), the latter more conspicuous and arranged in bundles. Cutaneous musculature as thick as 12% of body height. Parenchymal musculature composed of three muscular layers: a dorsal layer with diagonal decussate fibers (70 μm thick) and a supraintestinal layer (70 μm thick in holotype) and a subintestinal transverse layer (30 μm thick). Ventral nerve plate present.

Relative position mouth:pharyngeal pouch length, of 57%. Pharynx bell-shaped (Fig. 13E). Esophagus present, with 20% of pharynx length. Outer pharyngeal musculature consisting of a subepithelial layer (5 μm thick) of longitudinal muscle, followed by a layer (30 μm thick) of circular musculature. Inner pharynx musculature consisting of a subepithelial layer (40 μm thick) of longitudinal musculature followed by intermingled longitudinal and circular fibers (holotype).

Testes dorsal, located between supraintestinal parenchymal muscle layer and intestine. These testes extend from the level of the ovaries to shortly before root of pharynx. Laterally to the middle of penis bulb, sperm ducts bend dorsally above the level of the penis bulb, and subsequently bend anteriorly for a short length to open ventro-medially into the extrabulbar portion of the prostatic vesicle. This extrabulbar portion is located above the penis bulb (Figs. 14A, B). These sperm ducts lined with a squamous ciliated epithelium, that becomes cuboidal distally and full of sperm. This epithelium is surrounded by a 8-15 μm thick circular muscle, at some points decussate. Penis bulb conspicuous, elongate and strongly developed, extending from 1.8 millimeters anterior to penis papilla (paratypes F2738, F2696), which represents half of the length of the copulatory apparatus. The bulb consists of decussate, tightly packed muscle fibers; the penis bulb is ectally continuous with the common muscle coat and entally with the muscle around the intrabulbar portion of the prostatic vesicle. The extrabulbar portion of the prostatic vesicle is gourd- or ovoid- shaped, and is placed above the penis bulb. From the ventro-anterior aspect of the extrabulbar portion, the

prostatic vesicle continues as a canal that penetrates antero-dorsal section of the penis bulb. Inside the bulb, the prostatic vesicle is a dilated canal with slightly folded walls describing a curve as it runs initially ventrally, subsequently backwards and horizontally to advance into the anterior third or quarter of the penis papilla before continuing as the ejaculatory duct. Prostatic vesicle lined with a ciliated epithelium which is cuboidal in the extrabulbar portion, and columnar in the intrabulbar portion. Both epithelia are pierced by glands producing erythrophil granules. A tightly packed muscle of fibers variously oriented surrounds the prostatic vesicle. This muscle fibers are continuous with those of the penis bulb. Ejaculatory duct crosses the middle of the penis papilla. It is lined by a cuboidal, ciliated epithelium. This epithelium is surrounded by a conspicuous layer of circular muscle, tending to decussate muscle in some regions. This muscle layer is 80 μm thick in its proximal region and 10 μm thick in its distal region. In the proximal region, it constitutes a muscular cylinder with 300 μm in diameter, which represents four times the diameter of the ejaculatory duct (75 μm). Distally, the muscular cylinder is 50 μm in diameter, or twice that of the surrounded ejaculatory duct (25 μm). Penis papilla long, conical, with dorsal and ventral insertions at the same transverse plane. The papilla occupies whole of male atrium and most part of the female one (Figs. 14A, B). Papilla lined with a cuboidal epithelium. Glands producing cyanophil granules open through dorsal half of epithelium of penis papilla; the remaining papillar epithelium is crossed by glands producing eryhtrophil granules. The openings of these glands are specially abundant on distal half of the papilla. Subepithelial musculature of penis papilla consists of a dense 30μm thick layer of circular muscle, the innermost portion of which possesses intermingled longitudinal fibers (Fig. 14B). Male atrium not folded, lined by a cubic non ciliated epithelium, and underlain by a 10 μm thick layer of circular muscle, followed by a 20 μm thick layer of longitudinal muscle.

Ovaries ovoid, 300 μm in length, placed above the ventral nerve plate, and at a distance from anterior body tip equal to 34% of body length. Ovovitelline ducts emerge from dorso-lateral aspect of ovaries. Laterally to female atrium, they rise posteriorly and medially as they widen to double its own diameter, subsequently they narrow and unite dorsally to the common glandular ovovitelline duct (Figs. 14A, B). They receive shell glands into their distal, horizontal portion. Common glandular ovovitelline duct

horizontal, as long as half of female atrium. This common duct opens to the female genital duct, an anteriorly oriented projection from postero-dorsal region of female atrium.

Female atrium with a few longitudinal, lateral folds. The female atrium widens anteriorly to continue with the male atrium. Female:male atrial length, 1.4:1. Female atrium and female genital duct lined with a columnar 30µm high non-ciliated epithelium, the apical surface of which is erythrophil. This epithelium is crossed by two types of glands, producing erythrophil and xanthophil granules, respectively, the latter being scarcer. This epithelium and that of the female genital duct are surrounded by a thin, 10µm thick muscle layer of circular fibers with interwoven longitudinal fibers.

Remarks

Regarding the body aspect, *Cratera arucuia* sp. n. differs from all its congeners in the dorsal chromatic pattern. *Cratera hina* has a dorsal coloration somewhat resembling *C. arucuia*, but the former species lacks the marginal stripes of gray with fading inner margin. *Pseudogeoplana tricolor* (Riester, 1938) is the only species in *Pseudogeoplana* Ogren & Kawakatsu, 1990 (a collective group for geoplaninid species whose internal morphology is unknown) also resembles the new species in that the dorsal colors are similar and distributed in longitudinal stripes. However, the dorsal color of *P. tricolor* consists of a median yellow line, flanked by two paramedian dark lines and externally to these, two orange marginal lines.

Regarding the internal morphology, *C. arucuia* is easily differentiated from its congeners, and even from all other species of Geoplaninae by the unique location of the prostatic vesicle above the penis bulb.

Discussion

An ejaculatory duct widened distally is diagnostic for the genus, but as shown above, *C. hina*, *C. picuia* sp. n., and *C. arucuia* sp. n. do not present this widening, while in *C. crioula* and *C. joia* the widening is very slight or even absent. From Carbayo's et al. phylogentic tree (2013, Fig. 1 in the paper), most parsimonious explanation is that the distal widening of the ejaculatory duct evolved in the most recent

common ancestral of *Cratera* members and this widening was secondarily lost, or almost lost, in the ancestral of the ingroup *C. crioula* + *C. picuia* sp. n. + *C. arucuia*.

An anatomic comparison of the species in the genus against the phylogenetic framework supports the idea that diagnostic character states of the genus can be lost or modified within recently evolved in-groups of *Cratera*, hence puzzling species classification. This is the case for the widening of the ejaculatory duct, and also the uncommon location of the prostatic vesicle in *C. arucuia* sp. n. or the 90o rotation of the penis papilla in *C. cuarassu*. Other feature that is also not evenly distributed across the genus, namely the roof of the male atrium pierced by numerous cyanophil glands (*C. nigrimarginata* Rossi & Leal-Zanchet, 2017, *C. cuarassu*, *C. crioula* and *C. hina* are lack this trait). Eventhough, we consider that these features will help identify representatives of the genus and should be considered in the diagnosis.

With respect to the ontogenetic origin of the cavity within the penis papilla, we believe that it derives from the ejaculatory duct, and subsequently should be rather considered a dilation of the duct. This idea relies on that the lining epithelium of the cavity and the muscle fiber organization of its surrounding musculature are like that of the ejaculatory duct (the epithelium is ciliated and the surrounding muscle is circular). Therefore we coincide with Marcus' interpretation of the cavity in *C. taxiarcha*, quoted in the Introduction.

Taxonomic actions

Our results indicate the need of an emendation of the diagnosis of the genus to encompass species having secondarily lost the distal widening of the ejaculatory duct, as follows:

Diagnosis of *Cratera*. Geoplaninae with medium-sized body, 30–70 in length; body broad, flattened, slightly leaf-shaped; eyes monolobulated; pharynx cylindrical to bell-shaped, esophagus present; prostatic vesicle generally extrabulbar; penis papilla protrusible; ejaculatory duct usually dilated distally; male atrium not folded, generally not separated from the female one; roof of male atrium generally pierced by numerous cyanophil glands; ascending portion of the ovovitelline ducts anterior or lateral to the female atrium and joining each other above it; genital canal dorso-anteriorly flexed,

arising from the postero-dorsal or posterior region of the female atrium; female atrium funnel-shaped.

Acknowledgements

We are grateful to the COTEC - Instituto Florestal do Estado de São Paulo (#42.520/2007) and Reserva Biológica do Alto da Serra de Paranapiacaba – Insituto de Botânica (#3/2014) for licensing the field work. We also thank Cláudia Olivares, Débora Redivo, Júlio Pedroni, Leonardo Zerbone, Marcos Santos Silva, Marília Jucá and Welton Araújo (EACH, USP) for sampling help. Thanks to Geison Castro da Silveira, Lucas Beltrami, and Ítalo Silva de Oliveira Souza (EACH, USP) for histological processing. DLB thanks CNPq for a PhD-fellowship. FC has financial support from FAPESP (Proc. 2016/18295-5).

References

Carbayo F. Leal-Zanchet AM. 2001. A new species of terrestrial planarian (Platyhelminthes: Tricladida: Terricola) from South Brazil. *Brazilian Journal of Biology* 61(3): 437-447. http://dx.doi.org/10.1590/S1519-69842001000300013

Carbayo F, Álvarez-Presas M, Olivares MT, Marques FPL, Froehlich EM, Riutort M. 2013. Molecular phylogeny of Geoplaninae (Platyhelminthes) challenges current classification: proposal of taxonomic actions. *Zoologica Scripta* 42: 508–528. http://dx.doi.org/10.1111/zsc.12019

Carbayo F, Almeida AL. 2015. Anatomical deviation of male organs of land planarians from Rio de Janeiro, Brazil, with description of two new species of *Cratera* (Platyhelminthes, Tricladida). *Zootaxa* 3931: 27–40. http://dx.doi.org/10.11646/zootaxa.3931.1.2

Carbayo F, Álvarez-Presas M, Jones HD, Riutort M. 2016. The true identity of Obama (Platyhelminthes: Geoplanidae) flatworm spreading across Europe. *Zoological Journal of the Linnean Society* 177: 5–28. http://dx.doi.org/10.1111/zoj.12358

Cason JE. 1950. A rapid one-step Mallory-Heidenhain stain for connective tissue. *Stain Technology* 25(4): 225–226. http://dx.doi.org/10.3109/10520295009110996

Froehlich CG. 1956. Planárias terrestres do Paraná. Dusenia 7(4): 173–191.

Froehlich EM. 1955. Sôbre espécies brasileiras do gênero Geoplana. *Boletins da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, Série Zoologia* 19: 289–369. http://dx.doi.org/10.11606/issn.2318-5988.v2i0p3-10

Graff L. 1899. Monographie der Turbellarien: II. Tricladida Terricola (Landplanarien).Verlag von Wilhelm Engelmann, Leipzig, 574 pp.

Marcus E. 1951. Turbellaria brasileiros (9). *Boletins da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, Série Zoologia* 16: 5–215.

Negrete L, Brusa F. 2016. First report of the genus *Cratera* (Platyhelminthes, Geoplanidae) in Argentina, with description of a new species and comments on the species of the genus. *ZooKeys* 610: 1–12. https://doi.org/10.3897/zookeys.610.9465

Ogren RE, Kawakatsu M. 1990. Index to the species of the family Geoplanidae (Turbellaria, Tricladida, Terricola) Part I: Geoplaninae. *The Bulletin of Fuji Women's College* 28: 79–166.

Riester A. 1938. Beiträge zur Geoplaniden-Fauna Brasiliens. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 441: 1–88.

Rossi I, Fontoura M, Amaral S, Leal-Zanchet AM. 2014. A new species of land flatworm (Platyhelminthes: Continenticola) from areas of Araucaria Forest in southern Brazil. *Zootaxa* 3794: 514–524. http://dx.doi.org/10.11646/zootaxa.3794.4.2

Rossi I, Amaral SV, Ribeiro GG, Cauduro GP, Fick I, Valiati VH, Leal-Zanchet AM. 2016. Two new Geoplaninae species (Platyhelminthes: Continenticola) from Southern Brazil based on an integrative taxonomic approach. *Journal of Natural History* 50: 787–815. http://dx.doi.org/10.1080/00222933.2015.1084057

Rossi I, Leal-Zanchet AM. 2017. Three new species of *Cratera* Carbayo et al., 2013 from Araucaria forests with a key to species of the genus (Platyhelminthes, Continenticola). *Zookeys* 643: 1–32. http://dx.doi.org/10.3897/zookeys.643.11093

Stimpson W. 1950. Prodromus descriptionis animalium evertebratorum, etc. *Proceedings of the Academy of Natural Sciences of Philadelphia* 9: 19–31.

Tibiriçá LC. 1984. Dicionário Tupi-Português. Traço ed., São Paulo, pp. 200.

Figures

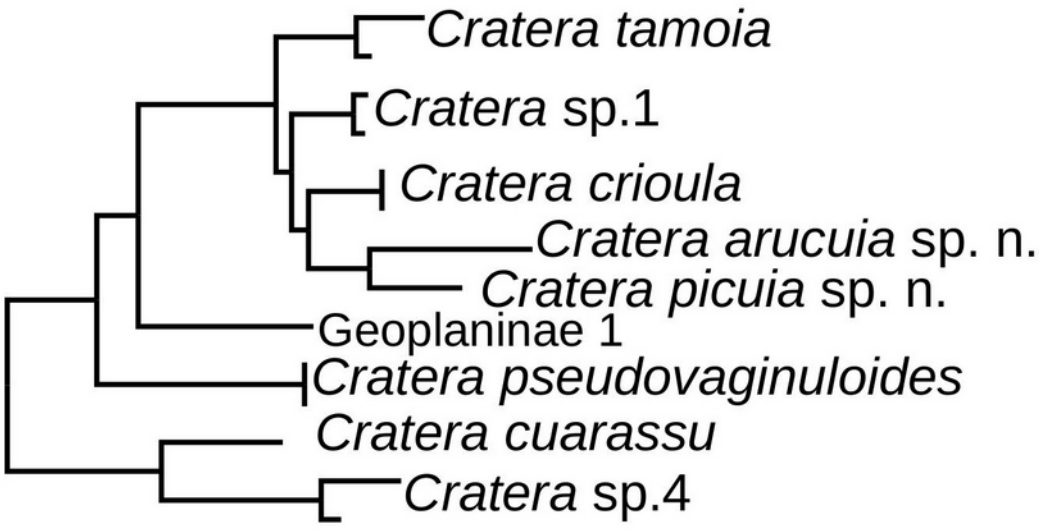


Fig. 1. Molecular phylogenetic relationships of species of *Cratera* (modified from Carbayo et al., 2013). *Cratera arucuia* sp. n. was named as *Cratera* sp. 2, whereas *Cratera picuia* sp. n. was named as *Geoplana hina* in Carbayo et al. (2013). Paratype F2783 is the terminal representing *C. arucuia* sp. n.

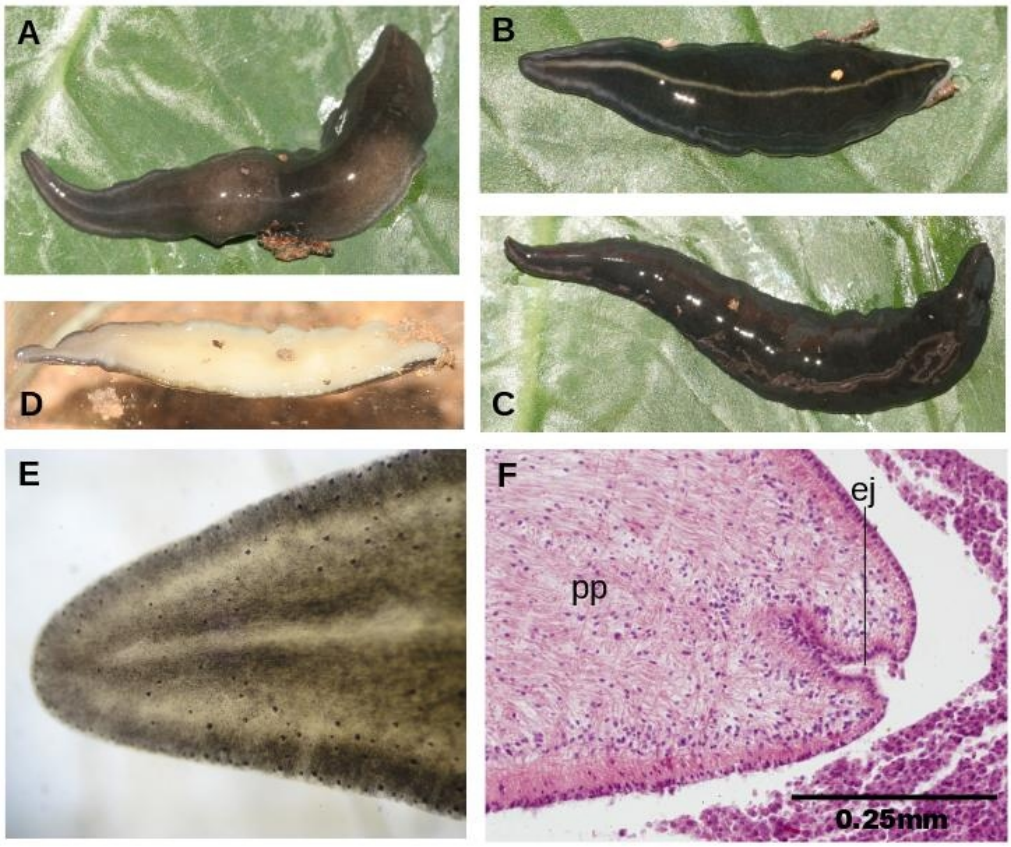


Fig. 2. Cratera crioula (Froehlich, 1955). (A): dorsal view of live specimen F3715. (B): dorsal view of live specimen F3712. (C): dorsal view of live specimen F3709. (D): ventral view of live specimen F3532. (E): anterior region of specimen F3709 after being cleared in clove oil; note eyes scattered onto dorsum. (F): photomicrograph of a sagittal section of the tip of penis papilla of holotype, showing the small dilation of the ejaculatory duct.

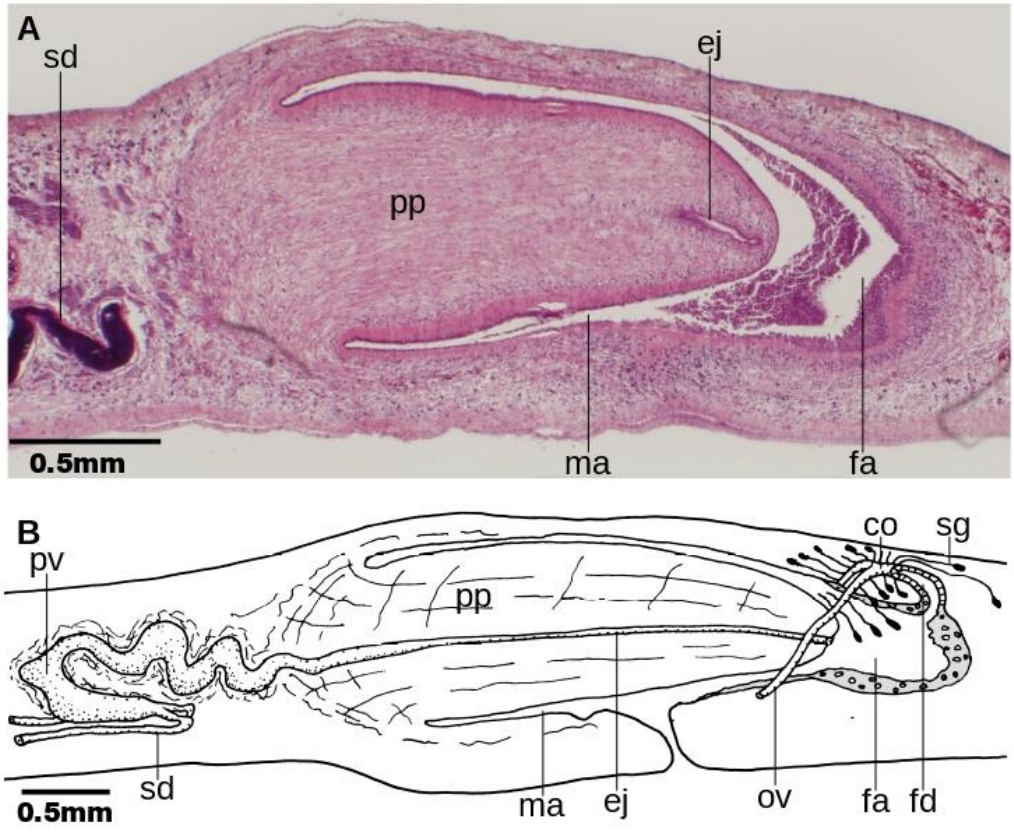


Fig. 3. Cratera crioula (Froehlich, 1955). (A): photomicrograph of a sagittal section of the copulatory apparatus of holotype. (B): diagrammatic representation of the copulatory apparatus of specimen F2946 from sagittal sections.

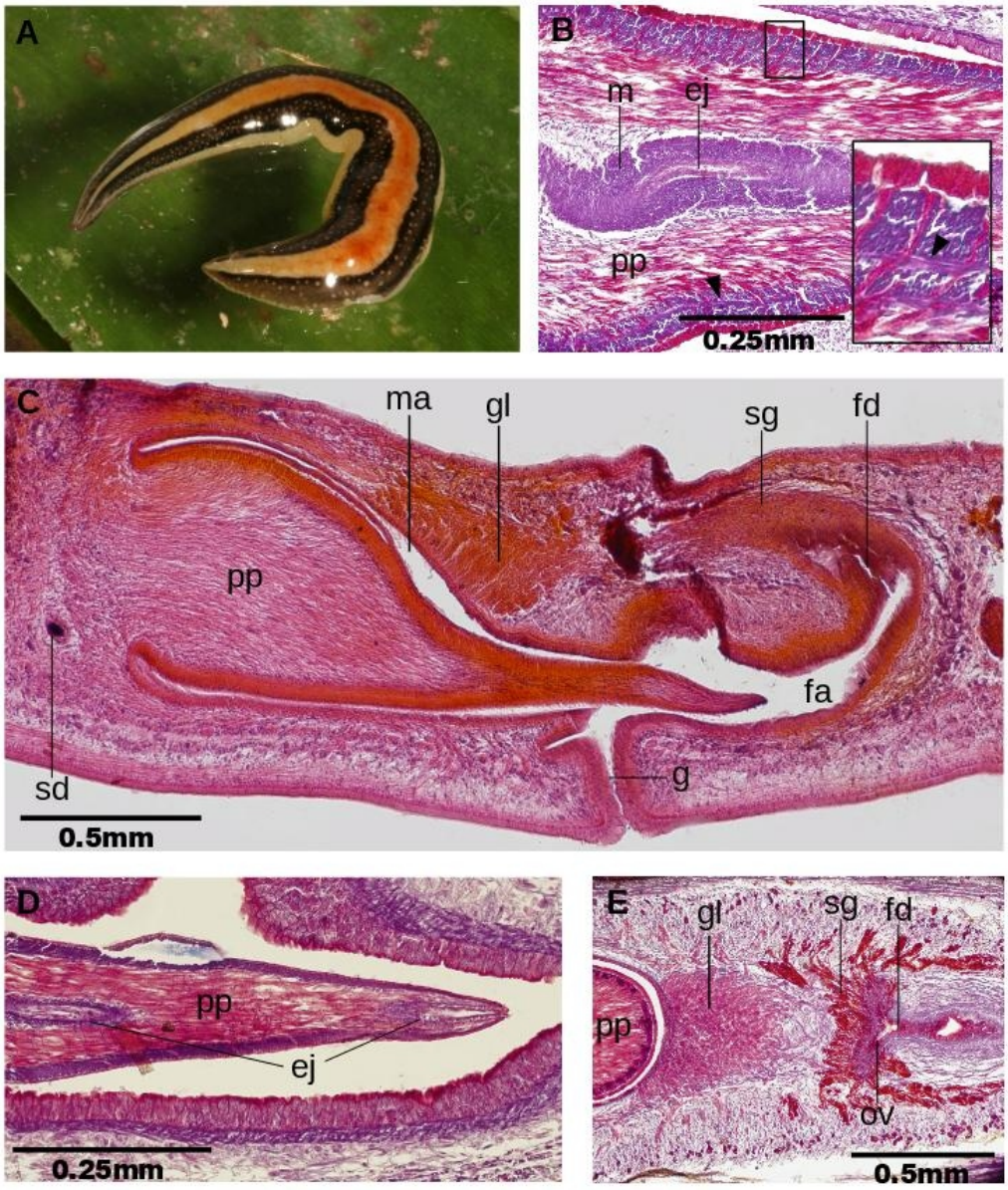


Fig. 4. Cratera hina (Marcus, 1951). (A): dorsal view of the live specimen F5682. (B): photomicrograph of a sagittal section of penis papilla of specimen F5682; arrowheads point to longitudinal muscle between two circular muscle underlying the papillar epithelium (detail in inset). (C): photomicrograph of a sagittal section of the copulatory apparatus of holotype. (D): photomicrograph of a horizontal section of the penis papilla tip of specimen F5682, showing the ejaculatory duct. (E): photomicrograph of a horizontal section of the copulatory apparatus of specimen F5682, showing glands piercing dorsal epithelium of male atrium and encountering of ovovitelline ducts with female genital duct.

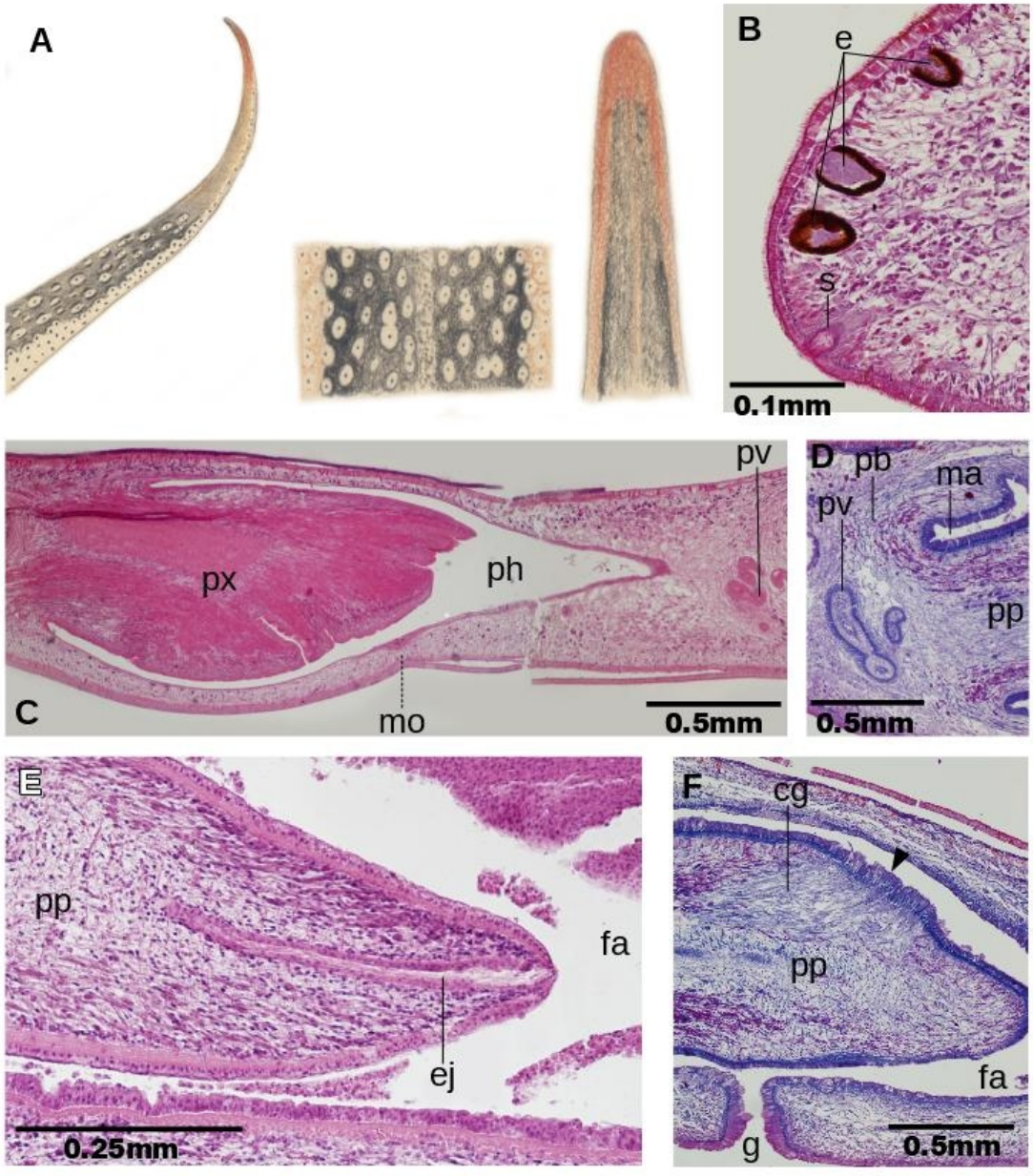


Fig. 5. Cratera joia (Froehlich, 1956). (A): original drawings by E. M. Froehlich, representing the coloration of type specimens and eye distribution. Leftmost drawing is a lateral view; two rightmost drawings are dorsal views of midbody and cephalic extremity. (B): photomicrograph of a transverse section of the anterior region of specimen F7239 showing eye and sensory pit; note cilia covering all epithelium. (C): photomicrograph of a sagittal section of the pharynx of syntype A or B. (D): photomicrograph of a sagittal section showing the extrabulbar position of the prostatic

vesicle in specimen F7239. (E): photomicrograph of a sagittal section of the tip of penis papilla of syntype A, showing the distal cavity of the ejaculatory duct. (F): photomicrograph of a sagittal section of the penis papilla of specimen F7239, showing the cyanophil glands and modified epithelium on the dorsal region of the penis papilla (arrowhead).

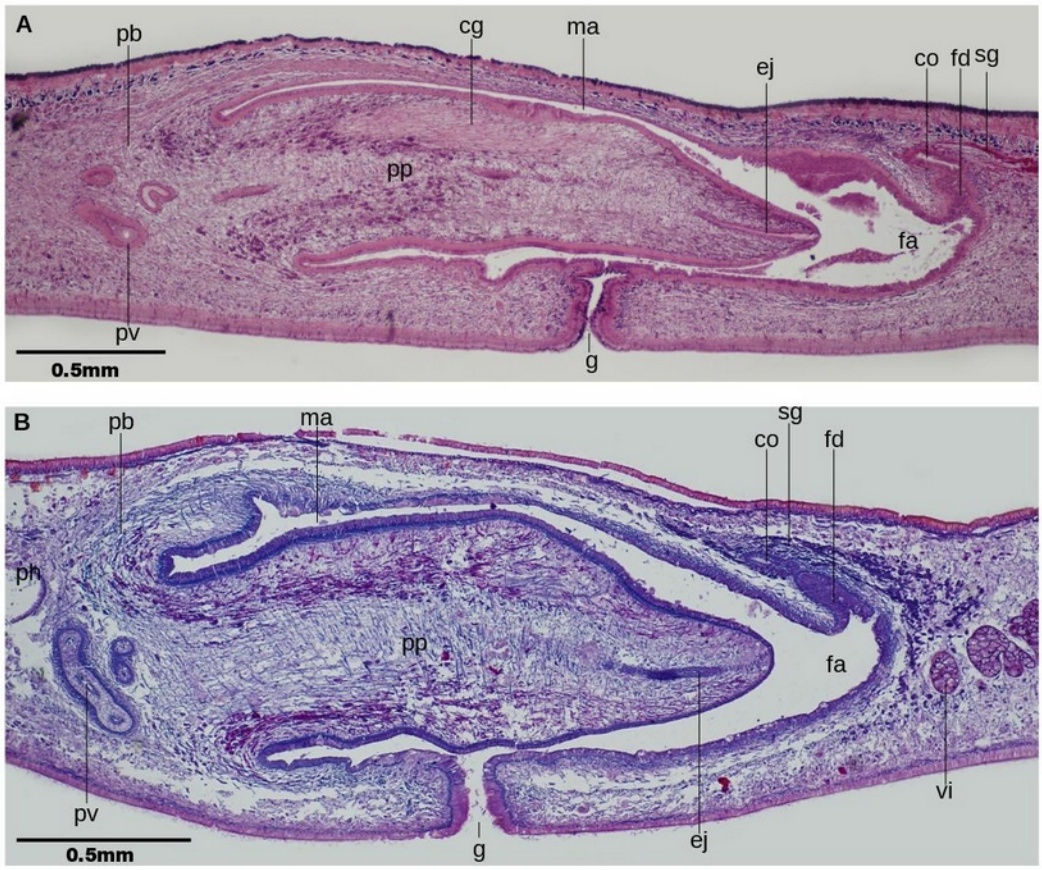


Fig. 6. Cratera joia (Froehlich, 1956). (A): photomicrograph of a sagittal section of the copulatory apparatus of syntype A. (B): photomicrograph of a sagittal section of the copulatory apparatus of specimen F7239.

Fig. 7. Cratera taxiarcha (Marcus, 1951). (A): dorsal view of specimen F3518. (B): photomicrograph of a sagittal section of the pharynx of specimen F3518. (C): photomicrograph of a sagittal section of the tip of papilla of the holotype, showing the distal cavity of the ejaculatory duct. (D): photomicrograph of a sagittal section of the tip of papilla of specimen F3518, showing the distal cavity of the ejaculatory duct.

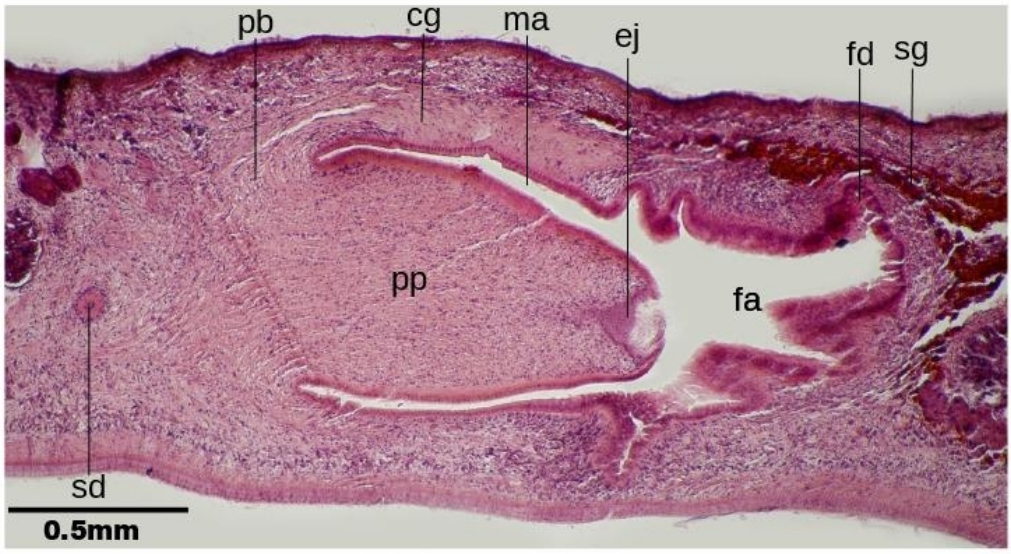


Fig. 8. Cratera taxiarcha (Marcus, 1951). Photomicrograph of a sagittal section of the copulatory apparatus of the holotype

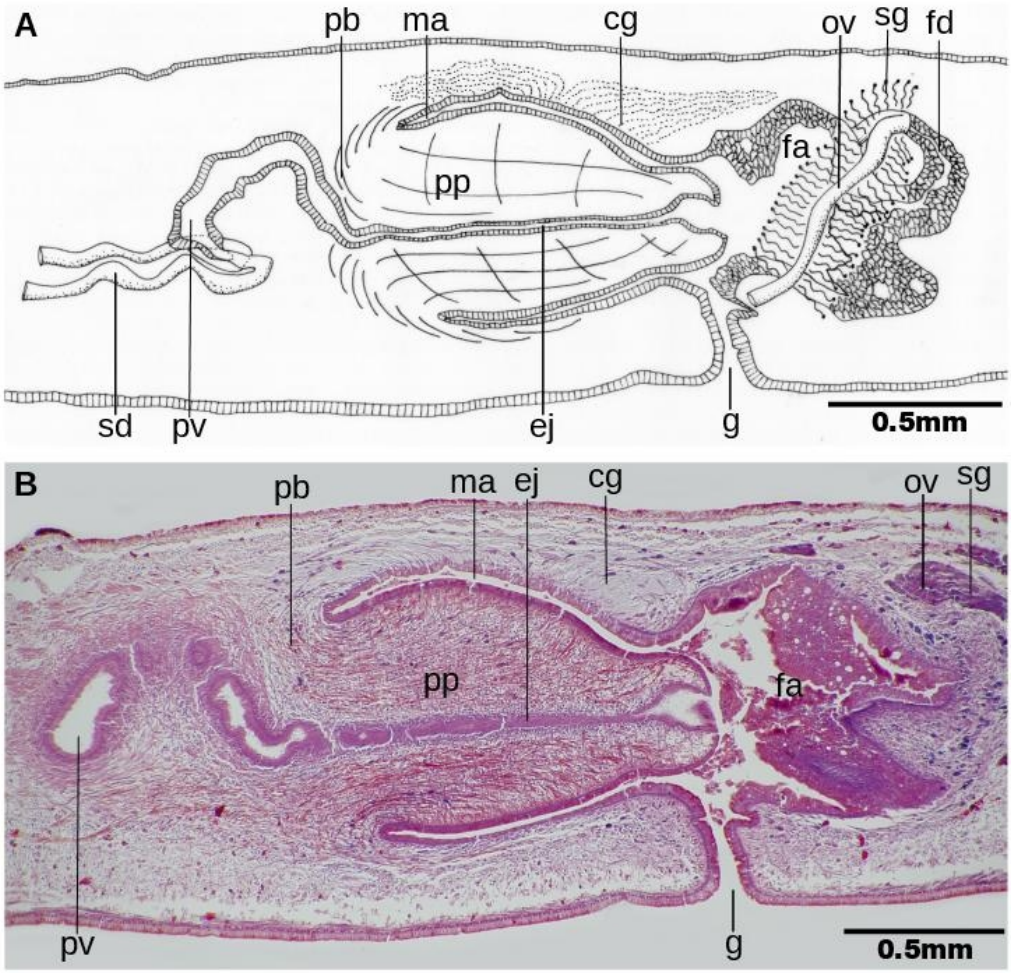


Fig. 9. Cratera taxiarcha (Marcus, 1951). (A) diagrammatic representation of the copulatory apparatus of specimen F3518 from sagittal sections. (B): photomicrograph of a sagittal section of the copulatory apparatus of specimen F3518.

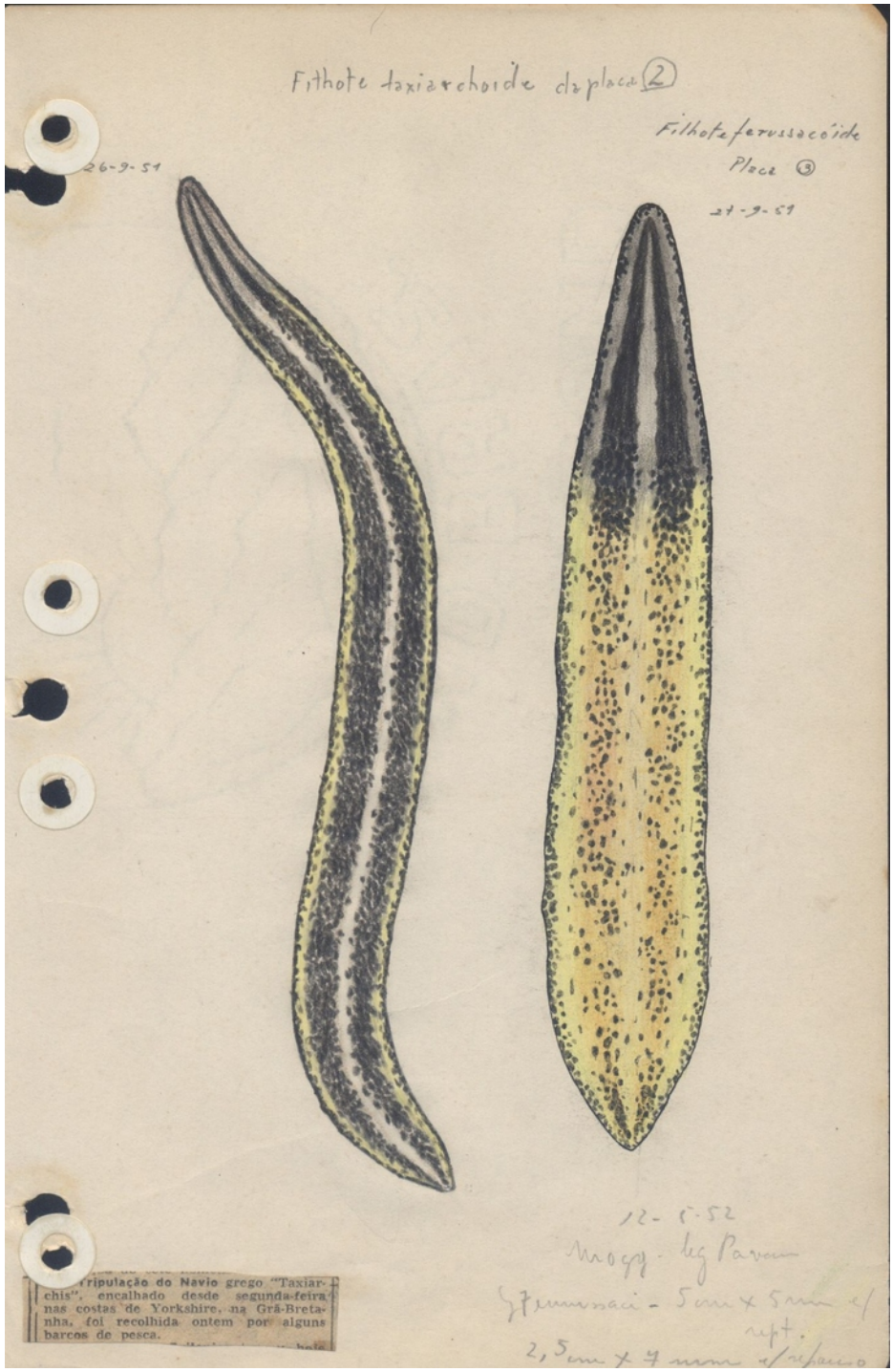


Fig. 10. Hand drawings, probably by E. M. Froehlich, of two hatchlings, one with the body color pattern of *C. taxiarcha* (left), another with the pattern of *G. ferussaci* (right) in Marcus's opinion. Note the newspaper clipping glued on bottom left corner, reporting the wreck of a ship called 'Taxiarchis'. See text for details.

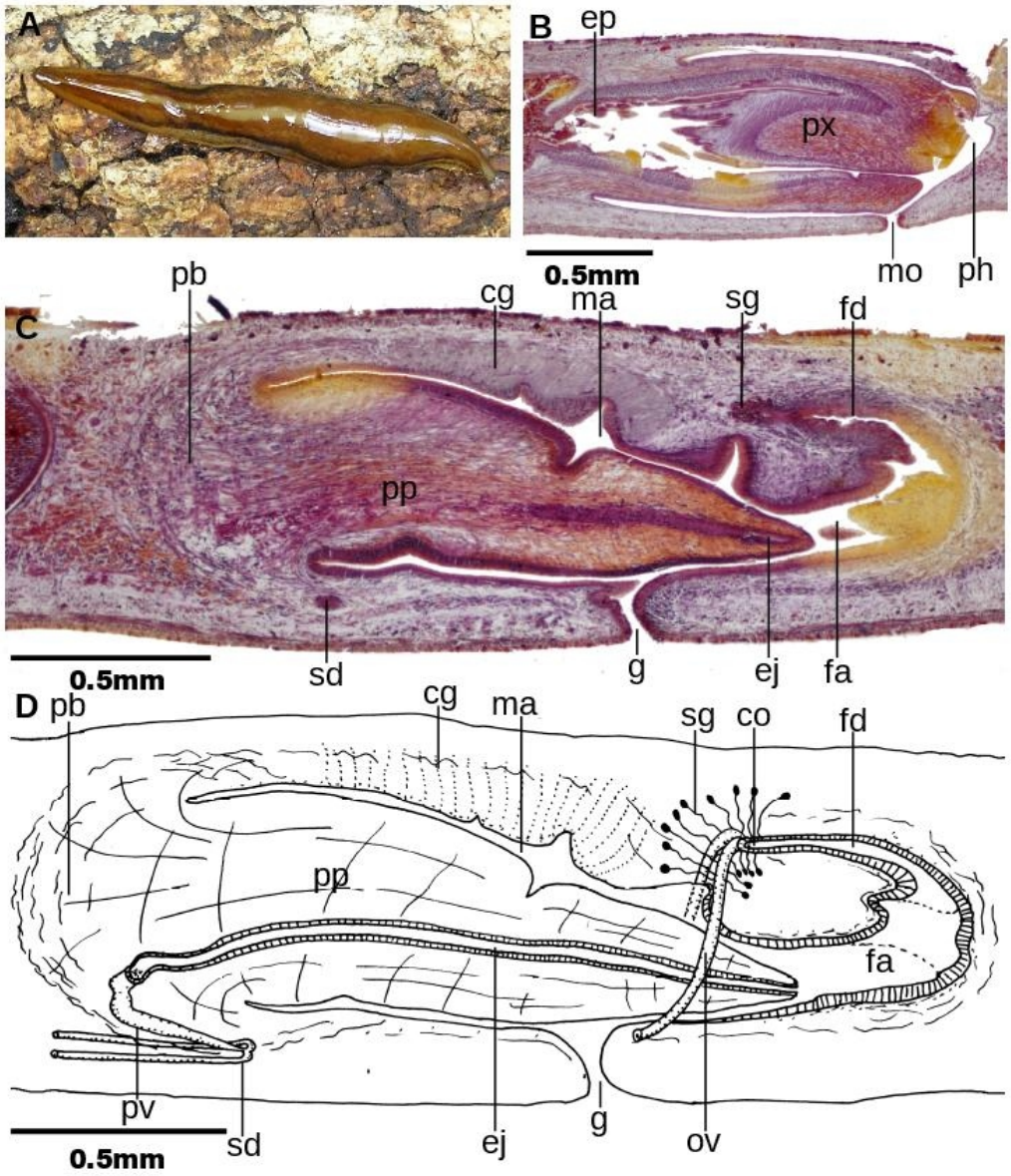


Fig. 11. Cratera picuia sp. n. Holotype. (A): dorsal view of the live specimen. (B): photomicrograph of a sagittal section of the pharynx. (C): photomicrograph of a sagittal section of the copulatory apparatus. (D): diagrammatic representation of the copulatory apparatus from sagittal sections.

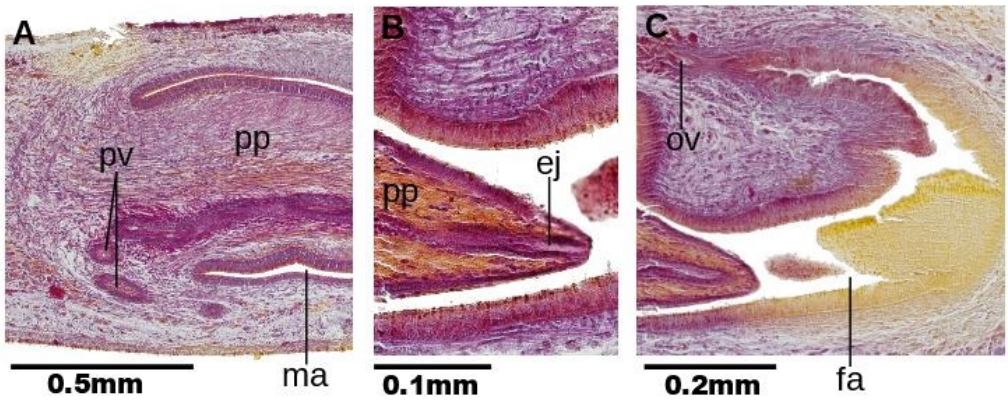


Fig. 12. Cratera picuia sp. n. Holotype. (A): photomicrograph of a sagittal section showing the intrabulbar position of the prostatic vesicle. (B): photomicrograph of a sagittal section of the tip of penis papilla. (C): photomicrograph of a sagittal section of the female genital canal and female atrium.

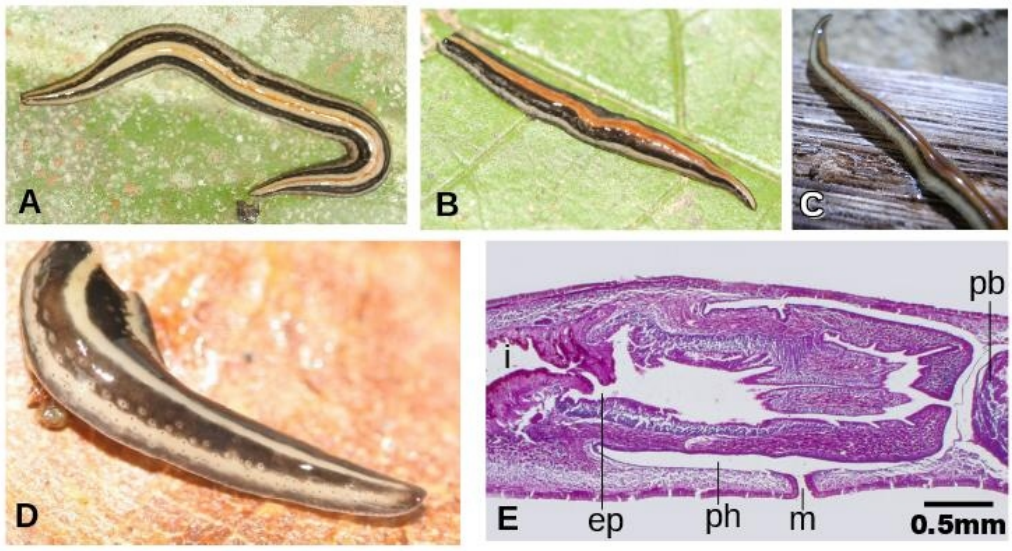


Fig. 13. Cratera arucuia sp. n. (A): dorsal view of the paratype F3094. (B): dorsal view of the paratype F3135. (C): dorsal view of the paratype F2784 showing thinner lateral stripes. (D): dorsal view of the paratype F3135 showing eye distribution on anterior region. (E): photomicrograph of a sagittal section of the pharynx of paratype F2696.

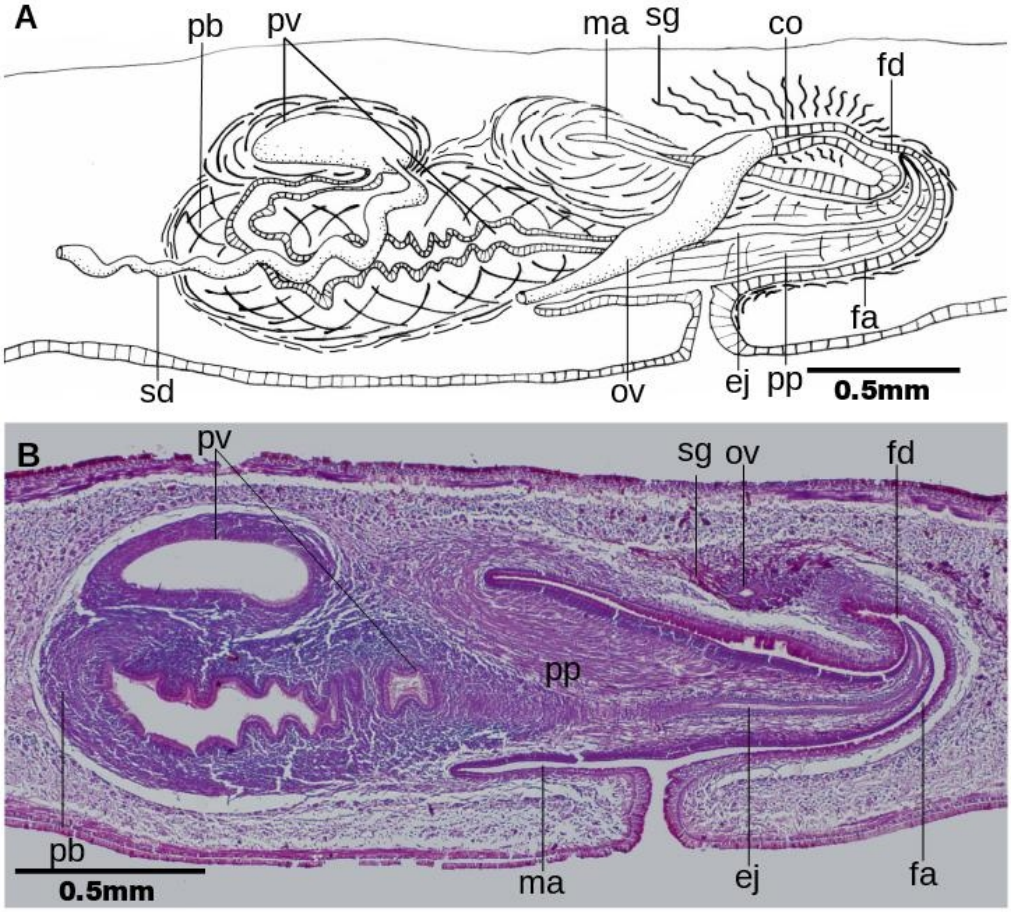


Fig. 14. Cratera arucuia sp. n. Holotype. (A): diagrammatic representation of the copulatory apparatus from sagittal sections. (B): photomicrograph of a sagittal section of the copulatory apparatus.

Chapter 2

Revision and description of six species of *Chearadoplana* (Platyhelminthes: Tricladida) with an emendation to the genus.

This is the accepted version of the following article: **Lago-Barcia D**, Silva MS, Carbayo F. Revision and description of six species of Choeradoplana (Platyhelminthes, Tricladida), with an emendation to the genus. Zookeys. 2021 Feb 11;1016:1-48. doi: 10.3897/zookeys.1016.59617.

Abstract

Living representatives of the Neotropical genus *Choeradoplana* Graff, 1896 (Geoplaninae, Tricladida, Platyhelminthes) are easily recognized by the typical shape of its head which is latero-laterally expanded, rolled-up and ventrally provided with two glandular cushions. In this study, the morphology and phylogeny (cytochrome C oxidase subunit I gene) of several species of land planarians are taxonomically investigated. Four out of the six species studied are new to science, namely: *Ch. eudoxiae* Silva and Carbayo, sp. nov., *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. *Ch. onae* Lago-Barcia and Carbayo sp. nov., *Ch. riutortae* Lago-Barcia and Carbayo sp. nov. *Ch. albonigra*, *Ch. eudoxiae* Silva and Carbayo sp. nov. deviate from the body shape pattern in that their head do not present lateral expansions nor glandular cushions, thereby becoming indistinguishable from its sister genus *Cephaloflexa* Carbayo and Leal-Zanchet, 2003. *Pseudogeoplana tristriata* (Schultze and Müller, 1857) is also redescribed from a newly collected specimen and was discovered to be a member of *Choeradoplana*. Graff (1899) also studied another specimen, however in this study it is concluded that it is not conspecific but rather a new species. The name *Pseudogeoplana aevipandemiae* Lago-Barcia and Carbayo sp. nov. is suggested for Graff's specimen.

Keywords: COI, flatworms, Geoplaninae, land planarians, rolled up, taxonomy.

Introduction

The simplicity of a planarian's (Tricladida) body, especially in the external aspect, entails additional efforts from taxonomists. Examination of more elaborate internal organs such as the muscular body systems and the copulatory apparatus on histological sections is usually required for identification beyond the subfamily level for these organisms. This situation also holds true for land planarians (Geoplanidae Stimpson, 1857). A few genera are identifiable by details in the shape of the head, such as the Asia-Pacific genera *Cotyloplana* Spencer, 1892 and *Pimea* Winsor, 1991 (Rhynchodeminae, Graff, 1896); or the Neotropical *Choeradoplana* Graff, 1896 and *Cephaloflexa* Carbayo and Leal-Zanchet, 2003 (Geoplaninae).

Choeradoplana and *Cephaloflexa* can be easily ascribed to either one or another genus based on the head shape, which is characteristically kept rolled up and backward in representatives of both genera. Furthermore, the two genera can be distinguished from each other in that the cephalic region in *Choeradoplana* is latero-laterally expanded and ventrally provided with two glandular cushions separated by a longitudinal groove, whereas the cephalic region in *Cephaloflexa* is ventrally concave and the anterior third of the body becomes thinner very gradually.

In a recent multi-gen phylogenetic analysis of the Geoplaninae, representatives of a species preliminarily ascribed in the field to *Cephaloflexa* turned out to be nested in the *Choeradoplana* clade (Carbayo et al., 2013). Therefore, the authors transferred it to that genus and the species is currently named *Ch. albonigra* (Riester, 1938) (Carbayo et al., 2013). However, the authors did not provide the morphological evidence of the taxonomic change.

In this paper, we describe and redescribe six species of Brazilian land planarians of the *Choeradoplana* genus. The external aspect of two of these species is similar to that of *Cephaloflexa*, namely the above-mentioned *Ch. albonigra*, and a new species described herein. We also studied a greenish individual recently collected and found out that it is a known species, *Pseudogeoplana tristriata* (Schultze and Müller, 1857). The remaining four species were also collected recently and are new to science. We additionally sequenced a fragment of the cytochrome C oxidase subunit I gene (COI) to

infer the phylogenetic relationships of the species treated herein, and the remaining representatives of the genus available in the Genbank.

Materials and Methods

Molecular analysis

Animal tissue destined for molecular studies was fixed in absolute ethanol and preserved at -20ºC. Genomic DNA was extracted using a standard ammonium acetate extraction protocol modified from Miller et al. (1988). The mitochondrial cytochrome oxidase I gene (COI) was amplified using the primers BarS (Álvarez-Presas et al., 2011), FlatwormCOIF (Sunnucks et al., 2006), and FlatwormCOIR (Lázaro et al., 2009). Standard PCR reactions were performed using Go Taq® DNA polymerase (Promega) in a total volume of 25 µl, which included 0.5 ml of each primer (10 mM) and 2 ml of template DNA. PCR conditions for the COI gene consisted of an initial denaturation at 98ºC for 3 min, followed by 35 cycles of denaturation at 98ºC for 10 sec, annealing at 45ºC for 30 sec, end extension at 72ºC for 1 min, and a final extension at 72ºC for 5 min. Amplification products (~750 bp) were purified using ExoSAP-IT (Affymetrix, OH) before sequencing both strands on a 3730 DNA Analyzer (Thermo Fisher Scientific). DNA sequence data were edited using BioEdit 5.0.9 (Hall 1999) and aligned using the online version of the Mafft v7 software program (Katoh et al., 2019) using the G-INS-i algorithm. The sequences of the mitochondrial COI gene reported in this paper were deposited in the NCBI/GenBank data libraries under accession numbers MW127833-MW127842 and MW148795.

The phylogenetic analysis included the newly obtained partial nucleotide sequences for the COI gene (Tab. 1), and additional sequences of the 12 species of Choeradoplana available in the NCBI/GenBank data libraries (Tab. 1) (Álvarez-Presas et al., 2011; Carbayo et al., 2013; Álvarez-Presas et al., 2014; Lemos et al., 2014; Carbayo et al., 2018). Two sequences belonging to the *Matuxia* genus (Carbayo et al., 2013) were selected as the outgroup (Tab. 1). PartitionFinder2 ver. 2.1.1 software (Lanfear et al., 2016) on XSEDE (CIPRES Gateway to Science (Miller et al., 2010) was used to discover the partitions and the evolutionary model which best fit the nucleotide dataset under the Akaike Information Criterion corrected (AICc) (Hurvich and Tsai,

1989). We estimated the phylogenetic relationships with a Bayesian Inference (BI) obtained using MrBayes v. 3.2.7 (Ronquist et al., 2012). The Markov chain Monte Carlo search was run up to 10 000 000 generations and stoprule activated to stopval=0.01. Samples were taken every 10,000 generations, discarding the first 25% trees as burn-in, after which the chain reached stationarity, which ensured that the average split frequencies between the runs were less than 1%. Maximum Likelihood (ML) was implemented in RaxML 7.2.+ software (Stamatakis, 2006) available on the CIPRES Science Gateway platform (Miller et al., 2010). Bootstrap support values (Felsenstein, 1985) were obtained from 10,000 replicates in ML analyses. The final trees were viewed and edited on the FigTree v. 1.4.2 software program (http://tree.bio.ed.ac.uk/software/figtree/).

Morphological analysis

All specimens included in this study (except for the Holotype SMF No. 702, Ch. albonigra) (Tab. 1) were collected between May 2008 and January 2010 from conservation areas located in the southern region of the Atlantic Forest. Specimens were manually collected during daylight hours from under rocks, fallen leaves, and logs, and during nighttime hours when the animals are more active. Slides of the holotype of *Ch. albonigra* were obtained on loan from the *Museum der Senckenbergischen Naturforschenden Gesellschaft* in Frankfurt.

The flatworms were examined, photographed in vivo and then killed with boiling water. Each specimen was divided into two tissue portions for histology and DNA extraction, respectively. Tissue portions destined for histology were fixed in 10% formaldehyde and preserved in 80% ethanol. Color descriptions of the body of living and preserved specimens follow the online palette RAL colours (RAL gemeinnützige GmbH©, available at https://www.ral-farben.de/uebersicht-ral-classic-farben.html?&L=1). Body portions were progressively dehydrated in an ascending series of ethanol and cleared in clove oil. Eye distribution was assessed from specimens cleared in clove oil. Body portions were subsequently embedded in Paraplast® Tissue Embedding Medium and the resulting blocks were sectioned at 5-7 μm intervals using a retracting rotary microtome. Ribbons of embedding medium were affixed with albumin-glycerol (1:1) on glass slides placed on a hot plate and stained with the method Mallory-

Heidenhain as modified by Cason (1950). Reconstructions of the copulatory apparatus were carried out from the histological sections using a camera lucida attached to a microscope. The relative thickness of cutaneous musculature was measured as a value relative to the body height in sections of the pre-pharyngeal region; space between normal and sunken longitudinal cutaneous layers was excluded from measurement. Specimens are deposited in the Museu de Zoologia da Universidade de São Paulo (MZUSP).

Abbreviations used in the figures

(cm) common muscle coat
(co) common glandular ovovitelline duct
(dd) decussate dorsal cutaneous muscles
(dm) diagonal decussate muscles
(e) eye
(ej) ejaculatory duct
(ep) esophagus
(er) erythrophil secretion
(fa) female atrium
(fd) female genital duct
(g) gonopore
(i) intestine
(lc) longitudinal cutaneous muscles
(ma) male genital atrium
(mk) Muskelgeflecht
(mo) mouth
(o) ovary
(ov) ovovitelline duct
(ph) pharyngeal pouch
(pp) penis papilla
(px) pharynx
(rg) rhabditogen glands
(r) retractor muscle

(sb) subintestinal transverse muscles
(sd) sperm duct
(sg) shell glands
(sk) sunken longitudinal cutaneous muscles
(sm) spermatophore
(sn) subneural transverse muscles
(sp) supraintestinal transverse muscles
(t) testis
(vi) vitellaria
(vn) ventral nerve plate

Results

Molecular results

Tissue of the only *Ch. eudoxiae* Silva and Carbayo sp. nov. individual was depleted during attempts to sequence it. COI sequences were obtained from the remaining 10 specimens representing the remaining three new species, *Ch. tristriata*, and *Ch. albonigra*. Sequence alignments resulted in a matrix with 54 terminals and 679 base pairs. PartitionFinder indicated two partitions (first and second codon positions and third codon position), each with a different evolutionary model, with the TIM substitution model having gamma-distributed rate variations across sites and a proportion of invariable sites (TIM + I+ G) for the first and second codons, and a GTR substitution model with gamma-distributed rate variation across sites and a proportion of invariable sites (GTR + I + G) for the third codon partition.

Phylogenetic analyses under the two optimality criteria (BI and ML) retrieved the *Choeradoplana* genus and all morphological species as monophyletic with high posterior probabilities and bootstrap value, respectively (Fig. 1), although the internal morphology of MZUSP PL 1108 and MZUSP PL 2277 specimens nested in the clade of *Ch. onae* Lago-Barcia and Carbayo sp. nov. could not be assessed. The genus was split into two large clades in both trees composed of the same species, with high PP and bootstrap value. All species studied herein (with the exception of *Ch. eudoxiae* Silva and Carbayo, sp. nov.) are nested in one of these large clades, which includes species

having an extrabulbar prostatic vesicle and lacking a penis papilla. However, independently from the optimality criteria applied, COI does not contain sufficient information to resolve the species interrelationships, thereby producing some polytomies and poorly supported clades.

Taxonomic account
Family Geoplanidae Stimpson, 1857
Subfamily Geoplaninae Stimpson, 1857
Choeradoplana Graff, 1896

Choeradoplana tristriata (Schultze and Müller, 1857)

Synonymy
Geoplana tristriata Schultze and Müller, 1857
Not *Geoplana tristriata* in Graff (1899)
Pseudogeoplana tristriata (Schultze and Müller, 1857) in part

Material examined. MZUSP 2271 (field code, F3226), sexually mature: Parque Estadual da Serra de Tabuleiro, State of Santa Catarina, Brazil (-27.94, -48.79). coll. F. Carbayo and co-workers, January 11th, 2009; transverse sections of the cephalic region on 6 slides; horizontal sections of the portion behind the cephalic extremity on 4 slides; transverse sections of the pre-pharyngeal region on 6 slides; sagittal sections of the pharynx and copulatory apparatus on 17 slides.

Distribution. Municipality of Blumenau and Parque Estadual da Serra de Tabuleiro, State of Santa Catarina, Brazil.

Diagnosis. Choeradoplana species with yellow green ground color, with three thin discontinuous longitudinal black lines; ventral side is zinc yellow. Copulatory apparatus compact, without penis papilla; female atrium funnel-shaped.

Description. The preserved specimen measures 22 mm in length and 2.5 mm in width (Fig. 2A). The body is slender and subcylindrical. The cephalic region is differentiated from the remaining body by means of a 'neck', laterally dilated and rolled up so that the ventral surface is provided with glandular cushions, and is facing out (Fig. 2B); the posterior extremity is pointed. The creeping sole is as wide as 90% of body width at the pre-pharyngeal region. The mouth is positioned at a distance from the anterior extremity equal to 60% of the body length, and the gonopore is at 74%.

The dorsal coloration consists of a yellow green (RAL 1018) ground color, with three thin discontinuous longitudinal lines of small black spots. These spots are less concentrated in the median line (Fig. 2A). The ventral side is zinc yellow (RAL 1018), except for a silver grey (RAL 7001) spot on the glandular cushions (Fig. 2A).

The eyes are formed by one pigmented cup of 80 μm in diameter (Fig. 2C). There are no clear halos around them. Eyes are absent in the very anterior extremity of the body; at 1.5 mm behind the anterior tip the eyes are marginally distributed in a row of 2 or 3 eyes; 3.8 mm posterior to the anterior tip, the eyes are placed in a single marginal row which runs along the whole body until posterior extremity, with each eye at a distance of ~0.3 mm from each other (Fig. 2B).

Sensory pits are 25 μm deep (Fig. 2C arrowhead), and are distributed ventro-laterally in a uniserial row between ~0.4 mm behind the anterior extremity to at least the ovary level. Abundant erythrophil gland cells pierce the dorsal and marginal epithelium in the pre-pharyngeal region. The entire epithelium is additionally pierced by scarce gland cells of two types, producing cyanophil and xanthophil granules, respectively. No glandular margin.

The cutaneous musculature of the pre-pharyngeal region comprises a subepithelial circular muscle, followed by a diagonal layer with decussate fibers, and a longitudinal muscle organized in tight bundles (Fig. 2D and 3A). This longitudinal muscle is 70 μm thick dorsally; it is ventrally divided into a normal, 35 μm thick muscle, organized in bundles with 4-8 fibers each, and a 50μm thick muscle sunken into the parenchyma, and constituted by scattered bundles with 5-12 fibers each (Fig. 3B). The relative thickness of the cutaneous muscle coat is 17%.

There are three parenchymal muscle layers in the pre-pharyngeal region (Fig. 3A and 3B): a well-developed dorsal layer of diagonal, decussate fibers (12-18 μm thick), a

transverse supraintestinal muscle (22-25 μm), and a transverse subintestinal muscle (30-35 μm).

The ventral longitudinal cutaneous muscle is modified into the retractor muscle in the cephalic region. This retractor muscle is delta-shaped in cross-section along 0.7 mm (or 3% of body length) from behind, 0.2 mm (or 1%) in the anterior extremity of the body (Fig. 3C), and its thickness is 24% of the height of the cephalic region. The dorsal decussate and subintestinal parenchymal muscles in this region are weak, whereas the supra-intestinal is strongly developed and mixed with dorso-ventral muscle fibers giving rise to the *Muskelgeflecht* (Graff, 1899) or interwoven muscle, and is 75 μm in thickness. A fourth subneural parenchymal muscle is present in the cephalic region, and is located beneath the central nerve system and above the retractor muscle. The paired glandular cushions are pierced by numerous rhabditogen cells. The arrangement of cutaneous and parenchymal muscles in the cephalic region and the glandular component of the cephalic cushions match those of the type species of the genus, *Choeradoplana iheringi* Graff, 1899.

The mouth is located in the middle of the pharyngeal pouch (Fig. 4A). It is a bell-shaped pharynx, with the dorsal insertion posterior to the ventral insertion about 45% of the pharyngeal length. An esophagus is not present. The pharyngeal pouch is lined with a non-ciliated, cuboidal-to-flat epithelium, underlain by a one-fiber thick layer of longitudinal muscle, followed by a 10 μm thick layer of circular muscle. The outer pharyngeal epithelium is cuboidal, ciliated, underlain by a longitudinal muscle (7.5 μm thick), followed by a circular muscle (45 μm thick) with interspersed longitudinal fibers; the inner epithelium is flat, ciliated, underlain by a circular muscle (62 μm thick) with interspersed longitudinal fibers. Numerous erythrophil and xanthophil gland cells open and discharge their contents through the distal portion of the pharynx.

The testes are dorsal, located between the intestinal diverticula, with some of them reaching the parenchymal supraintestinal transverse muscle (Fig. 2D and 3A). The testes are arranged in two paramedian rows. They extend from 1 mm (30% of body length) behind the level of the ovaries to 1.2 mm from the root of the pharynx. Sperm ducts run straight and immediately above the subintestinal parechymatic muscle. They distally penetrate the anterior region of the common muscle coat (Fig. 4B and 4C) to open into the proximal portion of the paired branches of the prostatic vesicle. The

prostatic vesicle consists of an anterior half of these paired branches and a distal unpaired half. This vesicle runs postero-dorsally to open into the dorso-anterior section of the male atrium. An ejaculatory duct and penis papilla are absent (Fig. 5A). The penis bulb is thick and constituted of numerous muscle fibers which are continuous with those underlying the epithelium of the male atrium. The prostatic vesicle is lined with a columnar-to-cuboidal epithelium, underlain by a thin longitudinal muscle (5 μm thick), followed by a 30 μm thick circular muscle interspersed with longitudinal fibers. The paired portion of the prostatic vesicle receives abundant erythrophil and xanthophil granules from the respective gland cells, while the unpaired portion receives abundant cyanophil and xanthophil granules.

The male atrium is long and narrow with folded walls. The anterior third of the atrium runs postero-dorsally; distal 2/3rd runs ventrally almost vertically above the gonopore canal. The atrium is lined by a cuboidal-non-ciliated epithelium, and underlain by an 80 μm thick circular muscle with interspersed longitudinal fibers. The male atrium is 1.2 times longer than the female atrium.

The ovaries are mature, ovoid, and 200 μm in length. They are located above the ventral nerve plate at a distance from the anterior body tip equal to 25% of its body length (5.5 mm from anterior tip). Ovovitelline ducts emerge from the dorso-lateral aspect of the ovaries, whereafter they run backwards above the ventral nerve plate. The ducts bend medianly, posteriorly to the female atrium, and subsequently ascend vertically and medianly to communicate with each other above the postero-dorsal section of the female atrium (Fig. 5B). The ovovitelline ducts open directly into a very short female genital canal lined by a cuboidal ciliated epithelium. A small number of small shell gland cells can be spotted around the junction of the two ovovitelline ducts.

The female atrium is funnel-shaped, not folded, and lined by a ciliated columnar-to-cuboidal epithelium, which is surrounded by circular muscle fibers with interspersed longitudinal fibers. This muscle is continuous with the common muscle coat. Most of the abundant gland cells discharging into the female atrium have a fine granular xanthophil and erythrophil secretion. The length:height ratio of the copulatory apparatus enveloped by the common muscle coat is 1.4:1.

Remarks

On the identity of our specimen. Schultze and Müller (1857) described *Geoplana tristriata* from near Blumenau, in the State of Santa Catarina. The original description reads: "*Geoplana tristriata*, pale yellowish-green, with three narrow, dark, longitudinal lines on the back; belly paler. Greatest breadth about the second third part of the length, where the mouth is situated. It likes to bend the head upwards. At the point of curvature on each side there is a closed packed group of eye-spots, which are continued in an irregular series to the posterior extremity. The anterior margin of the head appears to be destitute of eyes. Length 1 1/2 inch [38.1 mm]; breadth 1 1/2 line [3.2-3.7 mm]. Abundant."

There is no record of the deposition of the type series. It was probably not preserved. Our specimen was collected 115 km south from the type locality, and matches Schultze and Müller's species in all characteristics. The conspecificity of our specimen could be questioned since the copulatory apparatus is the most important organ assuring identification in triclads. However, this species combines a set of unusual features among Geoplanins: the color pattern of the body, the cephalic region bent to the dorsal side (actually only found in *Choeradoplana* and *Cephaloflexa* among Geoplaninae), and the absence of eyes in the very anterior tip of the body. Schultze and Müller's and our specimen sharing these uncommon attributes supports their conspecificity.

The species redescribed herein also matches all diagnostic characteristics of *Choeradoplana* and should therefore be transferred to this genus. The species is unique in the external aspect in that there are no other species of *Choeradoplana* with dorsal green color with three longitudinal dark stripes. Internally, *Choeradoplana bilix* Marcus, 1951; *Ch. crassiphalla* Negrete and Brusa, 2012; *Ch. langi* (Dendy, 1894); and *Ch. marthae* Froehlich, 1955 are similar to *Ch. tristriata* in the compact aspect of the copulatory apparatus, having a length:height ratio equivalent to 1.8:1 or less, as calculated in drawings (Marcus, 1951; du Bois-Reymond Marcus, 1951, Froehlich, 1959; Negrete and Brusa, 2012). However, *Ch. bilix*, *Ch. crassiphalla* and *Ch. marthae* possess a penis papilla (vs. absent in *Ch. tristriata*), and the female atrium of *Ch. langi* is a narrow canal (vs. a funnel-shaped cavity).

The identity of Graff's specimen and consequent taxonomic actions. Herman von Ihering collected one specimen in Taquara, State of Rio Grande do Sul, Brazil, which he identified as a member of this species. Ihering sent it to Graff (1899), who endorsed his identification, but only provided a description of the external aspect. Froehlich (1959) disagreed with Ihering's identification because of the body shape, the relative position of the mouth, and the different width of the paramedian dorsal stripes. Froehlich concluded that both Schultze and Müller's and Graff's species remain obscure (Froehlich, 1959), but did not propose taxonomic changes. Ogren and Kawakatsu (1990) considered Schultze and Müller's and Graff's specimens conspecific, and transferred the species to the *Pseudogeoplana* collective genus, which houses species lacking information about the internal organs, especially the copulatory apparatus. We agree with Froehlich's opinion that Graff's species is different from Schultze and Müller's species. Accordingly, we propose the name *Pseudogeoplana aevipandemiae* Lago-Barcia and Carbayo, sp. nov. for Graff's species. The specific epithet means 'from the times of the pandemic'. The epithet alludes to the COVID-19 pandemic and is intended to keep the memory of the negative effects caused by the six-month-long closure of the laboratories for the conclusion of this paper.

We did not find Graff's specimen in the museums where part of this collection was disseminated (Naturhistorisches Museum, Basel; Museum of Natural History, Vienna; Senckenberg Museum, Frankfurt; Zoological Museum, Hamburg; Natural History Museum, London). Therefore, we consider Graff's specimen lost.

Choeradoplana albonigra (Riester, 1938)

Synonymy

Geoplana albonigra n. sp. Riester, 1938

Notogynaphallia albonigra: comb. nov. Ogren and Kawakatsu, 1990

Choeradoplana albonigra: comb. nov. Carbayo et al., 2013

Material examined. Holotype SMF N° 702, sexually mature: Teresópolis, Rio de Janeiro, Brazil, coll. E. Bresslau, April 9th, 1914; transverse sections of a body portion

seemingly being close to the anterior tip of the body on 1 slide; sagittal sections of the pharynx and copulatory apparatus on 1 slide; anterior and posterior tips in Canada balsam on 1 slide.

Reserva Biológica Augusto Ruschi, municipality of Santa Teresa, State of Espírito Santo, Brazil. May 26-27th, 2008. MZUSP PL 1109 (field code, F2313), only anterior half of the body collected: transverse sections of anterior extremity on 10 slides; sagittal sections of a portion behind anterior extremity on 5 slides; horizontal sections containing testes on 32 slides. MZUSP PL 1113 (field code, F2391), sexually mature: transverse sections of anterior extremity on 9 slides; sagittal sections of ovaries and testes on 6 slides; sagittal sections of pharynx and copulatory apparatus on 11 slides.

Parque Estadual do Desengano, municipality of Santa Maria Madalena, State of Rio de Janeiro, Brazil. August 10-13th, 2009. MZUSP PL 2273 (field code, F3991), juvenile: horizontal sections of anterior extremity on 3 slides. MZUSP PL 2153 (field code, F4031), sexually mature: transverse sections of anterior extremity on 12 slides; horizontal sections of ovaries on 22 slides; transverse sections of pre-pharyngeal region on 4 slides; sagittal sections of pharynx and copulatory apparatus on 8 slides; horizontal sections of posterior extremity on 4 slides. MZUSP PL 2152 (field code, F4024), sexually mature: horizontal sections of anterior extremity on 7 slides; sagittal sections of ovaries on 19 slides; horizontal sections of testes on 21 slides; transverse sections of pre-pharyngeal region on 9 slides; sagittal sections of pre-pharyngeal region on 12 slides; sagittal sections of copulatory apparatus on 12 slides. MZUSP PL 1083 (field code, F4081), sexually mature: transverse sections of anterior extremity on 55 slides; sagittal sections of the ovaries on 25 slides; horizontal sections of testes on 9 slides; transverse sections of pre-pharyngeal region on 6 slides; sagittal sections of pharynx and copulatory apparatus on 38 slides; horizontal sections of posterior extremity on 24 slides.

Distribution. Reserva Biológica Augusto Ruschi, Santa Teresa, State of Espírito Santo; Parque Estadual do Desengano, Santa Maria Madalena, State of Rio de Janeiro; Municipality of Teresópolis, State of Rio de Janeiro, Brazil.

Diagnosis. Choeradoplana species with a white dorsum, covered by a wide median black band, darker at its margins; an additional thin black median stripe may be present. The anterior third of the body is progressively thinner to the pointed tip; its extremity has no lateral dilations or "neck" differentiating the head from the body. The ventral side of the cephalic region is concave and without glandular cushions. The prostatic vesicle is extrabulbar. The copulatory apparatus is relatively long; penis papilla absent, and the female atrium is roughly funnel-shaped.

Description. Live specimens range between 50-63 mm in length and 2-3 mm in width (n=2). Preserved specimens range between 45-73 mm in length and 2-4 mm in width (n=4). The body is slender and subcylindrical, with the anterior third becoming progressively thinner to the anterior tip. The anterior extremity is very thin and coiled up so that the ventral surface is facing out (Fig. 6A). The ventral side of the cephalic region is slightly concave with indistinct glandular cushions (Figs. 6B-D). The posterior extremity is pointed. The creeping sole is 80-86% of width in the pre-pharyngeal region (n=3) (Fig. 7A). Its mouth is at a distance from the anterior extremity ranging between 50.9-64.4% of body length, gonopore at 63.2-75.3% (n=3).

The ground color of the body is traffic white (RAL 9016). It is dorsally covered by a wide graphite black (RAL 9011) band, darker at its margins, as wide as 3/4th of the body width, in the middle of which runs a thin jet black (RAL 9005) stripe which is not apparent in some individuals. Anterior and posterior extremities of the body are slightly orangish. The color has faded out in preserved specimens. The dorsal graphite black band in the body tips of the holotype split into two brownish stripes.

The eyes are of one-pigment cup type, 25-45 μm in diameter; with no clear halos. They are marginally distributed in an irregular row of two-to-six eyes, from the anterior tip of the body (Figs. 6B-C and 7A), backwards to the posterior end. Anterior extremity devoid of eyes.

The sensory pits are 22-27 μm deep and ventro-laterally are distributed in a single row along approximately the anterior 1/7th of the body. The pits are absent at the very anterior tip of the body (300 μm).

Numerous rhabditogen cells open onto the dorsal surface of the body (Fig. 7B) in the pre-pharyngeal region and its margins; these margins are also pierced by scarce gland cells producing granular, erythrophil secretion. The ventral epithelium is pierced by scarce gland cells producing granular, xanthophil secretion, and abundant gland cells producing strong erythrophil secretion (Fig. 7C). There is no glandular margin.

The cutaneous musculature consists of a subepithelial circular muscle, followed by a diagonal layer with decussate fibers, and a strong longitudinal muscle organized in bundles (Figs. 7A-C). This longitudinal muscle is 81.2-175 μm thick dorsally; it is ventrally divided into a normal, 37.5-50 μm thick muscle, organized in bundles with 20-35 fibers each, and an equally thick muscle sunken into the parenchyma, and constituted by scattered bundles with 7-30 fibers each (Fig. 7B). A few dorsal longitudinal fibers are medianly intermingled with those of the parenchymatic dorsal layer of diagonal decussate fibers. The relative thickness of the cutaneous muscle coat is 22-25% (n=3).

The same parenchymal muscles as in *Ch. iheringi* are found in the pre-pharyngeal region, namely the dorsal decussate muscle (40-55 μm thick, n=2), transverse supraintestinal muscle (74-100 μm), and transverse subintestinal muscle (45-65 μm) (n=2) (Figs. 7A-C).

The cutaneous and parenchymal musculature is organized in the cephalic region as in *Ch. iheringi*. The retractor muscle of the head is delta-shaped in a cross-section along 0.3 mm (or 0.5% of body length) from behind, 0.1 mm (or 0.15%) of the anterior extremity of the body (Fig. 7C), and its thickness equals 36% of the height of the cephalic region. The Muskelgeflecht (Graff, 1899) is 18-25 μm thick (24% of body height). The subneural parenchymal muscle consists of a few scarce transverse fibers. The glandular cushions are composed of a relatively small quantity of rhabditogen cells (Figs. 7D-F).

The mouth is located at a distance from the anterior section of the pharyngeal pouch ranging between 55.1-78.9% (n=4) (Figs. 8A-C). It is a bell-shaped pharynx with dorsal insertion near the mouth level. An esophagus is absent. The outer epithelium of the pharynx is cuboidal, ciliated and underlain by a thin longitudinal muscle (3-5 μm), followed by a circular muscle (15-20 μm) with interspersed longitudinal fibers. The inner pharyngeal epithelium is ciliated, underlain by a circular muscle (50 μm thick; n=3) with longitudinal fibers interspersed. There is abundant granular secretion of three

types, cyanophil, erythrophil and xanthophil, respectively, and pierce the distal pharyngeal epithelium.

The testes are dorsal, located under the supraintestinal transverse muscle layer, partially placed between the intestinal diverticula. They extend from the level of the ovaries (a distance from the anterior extremity of the body equal to 27 % of the body length) to nearly the root of pharynx (53% of the body length). Sperm ducts run immediately above the subintestinal muscle layer, dorsally and slightly laterally to the ovovitelline ducts. Distal portions of sperm ducts contain sperm, and are surrounded by a circular muscle. Sperm ducts communicate with the two roughly horizontal branches of the extrabulbar portion of the prostatic vesicle. These branches open laterally into an irregular, pear-shaped cavity, which is located more or less under the anterior section of the penis bulb (Figs. 9A-C). The prostatic vesicle continues as an almost vertical, tubular portion inside the very dense penis bulb to bend posteriorly towards a loose small ring-shaped horizontal fold (or ‘small penis-shaped fold’, after Riester, 1938) which may be narrowed and elongated as a finger (Fig. 9A). This fold gives passage to the male atrium (Fig. 9D). The penis bulb is very thick and consists of very numerous muscle fibers which are continuous with those underlying the epithelium of the male atrium. There is no ejaculatory duct as a differentiated portion. The prostatic vesicle is lined with a columnar, ciliated epithelium. The very abundant secretions discharging into it are zoned along the prostatic vesicle: paired branches receive very fine granular erythrophil and pink-reddish staining secretion; the dilated portion takes gross granular erythrophil intensely reddish staining secretion; a proximal intrabulbar portion receives finely erythrophil secretion; the distal section takes both finely cyanophil granular secretion and xanthophil variously sized secretion granules (Fig. 9D). The extrabulbar portion is surrounded by interwoven muscle fibers, and the intrabulbar portion by a muscular layer of circular fibers interspersed with longitudinal ones, both portions are 20-35 μm thick. The loose small ring-shaped horizontal fold is lined with a 3-6 μm high non-ciliated epithelium and is surrounded by a few seemingly circular muscle fibers.

The male atrium can anatomically be divided into halves. The anterior half is slightly folded and narrow. The distal half is ample and is narrowed distally by a large, dorsal fold extending through both the male and female atria. The stroma of this fold is

strongly muscularized with longitudinal and oblique fibers. Additional lateral folds may be present in the distal half (Figs. 8C, and 9A).

A spermatophore can be found in the stroma of the large dorsal fold leveled with the gonopore in three specimens (Fig. 8B-C). The biological meaning of the position of the spermatophore will be discussed elsewhere.

The anterior half of the male atrium is lined with a 5 μm high non-ciliated, infranucleated epithelium which is pierced by scarce gland cells producing fine erythrophil granules, and by gland cells producing variously sized xanthophil granules. This epithelium is surrounded by a 20-60 μm thick dense muscle of very thin muscle fibers (2 μm), followed by a muscle (up to 150 μm thick) of gross (4 μm) fibers. The posterior half of the male atrium is lined with an epithelium which is pierced by gland cells producing erythrophil granules. An intensely reddish erythrophil is found beneath this epithelium secretion. The lining epithelium of the posterior half of the male atrium is surrounded by a circular muscle (18-45 μm), followed by a longitudinal muscle (80-150 μm) (n=3). There is a clump of sperm within the stroma of the large atrial fold leveled with the gonopore in three specimens (F2391, F4024 and F4081) (Figs. 4A).

The ovaries are mature, very elongated, and club-shaped due to the dilated anterior extremity. The thin portion can be divided into smaller segments. The size of the ovaries ranges between 700-1200 μm in length and 120-170 μm in width (n=4). They are located above the ventral nerve plate, and at a distance from the anterior extremity equal to 27.1-31.3% of the body length (n=2). Ovovitelline ducts emerge from the dorso-lateral aspect of the ovaries and run above the nerve plate. The proximal segment of the oviducts is dilated and contains sperm (n=4). They ascend posteriorly and medially laterally to the female atrium, then unite dorsally to the common glandular ovovitelline duct (Figs. 4A and C). The distal portion of the oviducts is pierced by shell gland cells. The common glandular ovovitelline duct is downwards directed; it is continuous with a posteriorly and upward directed diverticulum of the female atrium, i.e. the female genital canal. The female atrium is roughly funnel-shaped, narrowed by a large a dorsal fold continued with that of the male atrium. The female genital duct is lined with epithelial cells, with the apical portion containing fine erythrophil granules, and is surrounded by a thin layer of circular and longitudinal muscle fibers.

The female atrium is lined with a columnar, non-ciliated epithelium, and is pierced by two types of cells producing erythrophil and cyanophil granular secretions, respectively. The female atrium is as long as half the male atrium. The common muscular coat of the copulatory apparatus is composed of a weak layer of intermingled fibers; it is 20–40 μm thick in the anterior section, and thinner in the posterior section. The length:height ratio of the copulatory apparatus enveloped by the common muscle coat ranges between 3.0-3.5:1 (n=5; mean 3.2:1).

Behavioral note. Creeping on the Petri dish, the animals sometimes rises up to 3/4th of the body from the substrate and swings to the sides as they would be searching for ground. When touched, they can react by tumbling. A similar behavior, named ‘escape reaction’, was observed for Ch. marthae by Froehlich (1959).

Remarks

This species was originally described as *Geoplana albonigra* Riester, 1938, from Teresópolis, State of Rio de Janeiro, Brazil. The external aspect and the internal morphology of the pharynx and copulatory apparatus were given in the original description. The species was later transferred to the recently proposed new genus *Notogynaphallia* Ogren and Kawakatsu, 1990, erected for species of Geoplaninae without penis papilla and dorsally located female genital canal. Based on morphological and molecular information, Carbayo et al. (2013) transferred the species to *Choeradoplana*, but they did not provide morphological evidence supporting that taxonomic decision.

On the identity of our specimens. Our specimens and the holotype of *Ch. albonigra* are much alike with each other, with the exception of the size of the male and female atria. Whereas the male and female atria are relatively narrow in the holotype, these atria are higher in two out of four mature individuals. Differences of the same nature have been observed in other land planarians (e.g., *Pasipha pasipha* (Marcus, 1951); *Obama josefi* (Carbayo and Leal-Zanchet, 2001)), and might have been caused by the physiological state of the individuals such as a recent copula, as seems to be the case of the specimens bearing a spermatophore.

The systematic position of *Ch. albonigra*. Riester described the species from a single individual and assigned the species to *Geoplana*. In Riester's description, there is no reference to the inner structures of the cephalic region, nor the cutaneous muscle coat. The cephalic region of the holotype is embedded in Canada balsam on a histological glass slide. Our study revealed a set of additional aspects, including the delta-shaped retractor muscle of the head and the insunk ventral longitudinal cutaneous muscle which only agree with *Choeradoplana*. Our molecular data also support this conclusion.

However, *Ch. albonigra* deviates from the genus in the body shape, since its anterior third thins progressively towards the anterior extremity, with the latter also lacking the typical glandular cushions of *Choeradoplana*. Accordingly, the diagnosis of the genus is revised below.

Choeradoplana eudoxiae Silva and Carbayo sp. nov.

Material examined. Holotype MZUSP 2272 (field code, F3417), sexually mature: Floresta Nacional de São Francisco de Paula, State of Rio Grande do Sul, Brazil, (-29.43628, -50.37369). coll. F. Carbayo and co-workers, January 22nd, 2009; transverse sections of the cephalic region on 7 slides; horizontal sections of ovaries on 4 slides; transverse sections of the pre-pharyngeal region on 4 slides; sagittal sections of the pharynx and copulatory apparatus on 8 slides; the posterior extremity on 3 slides.

Distribution. Only known from the type locality, Floresta Nacional de São Francisco de Paula, State of Rio Grande do Sul, Brazil.

Etymology. The specific epithet pays homage to the late Prof. Eudóxia Maria Froehlich, *October 21st, 1928 — † September 26th, 2015, for her insightful life lessons and lasting contribution to the knowledge of the neotropical planarian fauna over 60 years.

Diagnosis. Choeradoplana species with pastel yellow back and brown fawn spots, more concentrated in the paramedian region. Its anterior extremity has no lateral dilations or

“neck” differentiating its head from its body. The ventral side of the cephalic region is concave, and without distinct glandular cushions. The extrabulbar portion of the prostatic vesicle has paired branches and an unpaired, roughly rounded section; the intrabulbar portion is a dilated vertical duct. Penis papilla is absent.

Description. The live holotype measured 38 mm in length, and 1.5 mm in width. Preserved, it measured 27.5 mm in length and 2 mm in width. Its body is slender and subcylindrical, with the anterior 1/8th becoming progressively thinner towards the anterior tip. The anterior extremity is rounded and the posterior is pointed. The dorsal side is convex, while the ventral side is slightly convex. The anteriormost body portion is approximately five millimeters long and rolled up so that the ventral side is facing upwards (Figs. 10A-C). This ventral surface is concave, without distinct glandular cushions. This ventral surface is flat in the preserved holotype. Its creeping sole is as wide as 75.5% of body width at the pre-pharyngeal region. Its mouth is 14.5 mm (52.7% of body length) from the anterior extremity, and the gonopore is 16.8 mm (61.1%).

The dorsum ground color of the body is pastel yellow (RAL 1034) with fawn brown (RAL 8007) spots (Fig. 10A-C); these spots are more densely distributed in the paramedian regions, some merged with each other. The ventral side is cream (Fig. 10D). The cephalic extremity is greyish dorsally and ventrally. The body color faded on the preserved holotype.

The eyes are one pigmented-cup type of 25-30 μm in diameter. There are no clear halos around them. Since the very anterior histological sections are lost, it could not be ascertained whether they occur in this body region (Figs. 10C-D). Posteriorly, the eyes are marginal along the body length.

Sensory pits are 17-22.5 μm deep, distributed ventro-laterally in a uniserial row from the anterior sections of the body (approximately 0.2 mm of the anteriormost body were lost) to 4.5 mm behind it.

Abundant rhabditogen cells open onto the dorsal surface of the body and its margins in the pre-pharyngeal region. The epithelium of the margins is also pierced by gland cells producing erythrophil granules (Fig. 11A-D). The ventral epithelium is pierced by three types of gland cells, namely scarce gland cells producing granules of

cyanophil secretion with a dark, dirty aspect, gland cells producing cyanophil granules, and gland cells producing an erythrophil secretion. There is no glandular margin.

The cutaneous musculature consists of a subepithelial circular muscle, followed by a diagonal layer with decussate fibers, and a longitudinal muscle organized in bundles (Figs. 11A and 11C). This longitudinal muscle is 57.5 μm thick dorsally and arranged in bundles of 50-90 fibers each, whereas ventrally it is divided into a normal, 30 μm thick muscle of bundles (with 8-15 fibers each), and an insunk muscle with 70 μm thick bundles (with 16-32 fibers each) (Fig. 11A). The relative thickness of the cutaneous muscle coat is 20%.

In the pre-pharyngeal region, the same parenchymal muscles as in Ch. iheringi, namely the dorsal decussate muscle (52-55 μm thick), transverse supraintestinal muscle (20-22 μm), and transverse subintestinal muscle (12-15 μm) (Figs. 11A and 11C).

The cutaneous and parenchymal musculature is organized in the cephalic region as in *Ch. iheringi*. The muscle retractor of the head is delta-shaped in a cross-section along about 0.5 mm (or 1.8% of body length) starting from 0.1 mm behind anterior extremity of the body (Fig. 11B and 11D), and its thickness equals 36% of the height of the cephalic region. The Muskelgeflecht is 32 μm thick (22% of body height). The subneural parenchymal muscle consists of a few transverse fibers. The glandular cushions are composed of a relatively small quantity of rhabditogen cells (Fig. 11C).

The central nervous system presents a ventral nerve plate (70-85 μm thick or 9-11% of body height) in the pre-pharyngeal region.

The mouth is located in the middle of the pharyngeal pouch. The pharynx is bell-shaped (Fig. 12A). An esophagus is absent. The outer pharyngeal epithelium is underlain by an 8-μm thick longitudinal muscle, followed by a 15-μm thick circular muscle. The inner pharyngeal epithelium is underlain by a circular muscle layer with longitudinal fibers interspersed (20 μm thick) (Figs. 12A-B).

The testes are dorsal, 90-150 μm in diameter, located under the supraintestinal transverse muscle layer, and partially placed between the intestinal diverticula. The anteriormost testes are located 0.9 mm anterior to the ovaries (or 21% of the body length); posteriormost near the root of the pharynx (49% of the body length). Sperm ducts run immediately above the subintestinal muscle layer, dorsally and slightly internal to the ovovitelline ducts. Distal portions of sperm ducts contain sperm and are

surrounded by a 20 μm thick circular muscle. These ducts communicate with the respective short branch of the prostatic vesicle (Figs. 12C-D). The paired branches run posteriorly. The extrabulbar portion of the prostatic vesicle consists of these paired branches and an unpaired, roughly rounded section with pleated wall receiving the branches. The intrabulbar portion of the prostatic vesicle is elongate and runs dorsally and posteriorly. The passage of the prostatic vesicle to the proximal region of the male atrium is narrowed by an annular fold (Fig. 12D). There is no ejaculatory duct, nor penis papilla. The penis bulb is very thick and consists of numerous muscle fibers which are continuous with those underlying the epithelium of the male atrium. The prostatic vesicle is lined with a columnar, ciliated epithelium underlain by a dense layer (20 μm thick) of interwoven circular and longitudinal muscle fibers. The epithelium of the diverticula and that of the anterior section of extrabulbar section of prostatic vesicle are pierced by numerous gland cells producing strong erythrophil (pinkish) granules. The epithelium of the posterior section of the extrabulbar portion is pierced by gland cells producing abundant erythrophil granules. Two types of gland cells pierce the epithelium of the intrabulbar portion of the vesicle; one type is very abundant, and produces cyanophil granules, while the second type produces erythrophil granules.

The male atrium is elongated, anatomically divided into two halves. The anterior half is horizontal, slightly folded and narrow. The posterior half is wider, and provided with two large transverse and oblique folds. The atrium is lined with a 7 μm high epithelium, and pierced by two types of gland cells producing erythrophil and cyanophil granules, respectively. The atrial epithelium is underlain by a 20 to 35 μm thick circular muscle with longitudinal fibers intermingled (Fig. 12D and 13A).

The ovaries are mature, rounded, about 100 μm in diameter. They are located 8.9 mm from the anterior extremity of the body (24.7 % of body length), and above the ventral nerve plate. The ovovitelline ducts emerge from the dorso-lateral aspect of the ovaries and run above the nerve plate; their proximal section contains sperm. Laterally to the female atrium, they rise posteriorly to unite dorsally to the common glandular ovovitelline duct (Figs. 13A-B). This common duct is located behind the female atrium, and runs downwards to open into a canalicular projection of the posterior section of the female atrium.

The female atrium is irregular, provided with 2-3 lateral and dorsal folds. This atrium is as long as half the male atrium, and is lined with an 8-10 μm high epithelium, the cells of which are erythrophil in their subapical portion. This epithelium is pierced by gland cells producing cyanophil granules (Fig. 13B), and is underlain by a 10 μm thick muscle of circular and longitudinal muscle fibers.

The common muscular coat is well developed and continuous with the penis bulb. This coat wraps the intrabulbar portion of the prostatic vesicle, and the male and female atria. The length:height ratio of the copulatory apparatus enveloped by the common muscle coat is 2.2:1.

Behavioral note. When touched with a finger on the posterior end, the animal reacted by rolling forward. Firstly, it lifted its posterior extremity forward to touch the ground at the level of the midbody so that the body forms a loop. Next, the loop moved forwards until the anterior third of the body detached from the ground, which subsequently lengthened and touched the substrate. By doing so, the animal moved forward a distance equivalent to half its body length in approximately one second. It then immediately repeated this whole movement afterwards.

Remarks

The species described herein matches all diagnostic characteristics of *Choeradoplana*, except for the glandular cushions of the cephalic region, which are not developed. This is so notable that the species was initially assigned to *Cephaloflexa* upon examination of the live and preserved specimen. Regarding the body shape, *Cephaloflexa* is characterized by having “the anterior third very gradually narrowing, without constriction or widening and without grooves on the ventral surface. The anterior tip rolled upwards and is ventrally concave” (Carbayo and Leal-Zanchet, 2003). *Ch. albonigra* is similar in this aspect to the genus *Cephaloflexa* and to *Ch. eudoxiae* Silva and Carbayo sp. nov. Unfortunately, it was not possible to sequence DNA from the small tissue available of *Ch. eudoxiae* Silva and Carbayo sp. nov., and the homology test of the particular body shape of these two species remains an open question.

The remaining diagnostic attributes of *Choeradoplana* are present in *Ch. eudoxiae* Silva and Carbayo sp. nov., such as the ventral cutaneous longitudinal muscle partially

sunken into the parenchyma; a retractor muscle of the cephalic extremity with a delta shape in transverse section; and a dorsal decussate parenchymatic muscle modified in the cephalic region into the *Muskelgeflecht*.

The body color of the *Ch. eudoxiae* Silva and Carbayo sp. nov. resembles that of some congeners in the brownish ground color with dark black or dark brown spots over it, namely *Choeradoplana abaiba* Carbayo et al., 2018, *Ch. agua* Carbayo et al., 2018, *Ch. banga* Carbayo and Froehlich, 2012, *Ch. benyai* Lemos and Leal-Zanchet, 2014, *Ch. bocaina* Carbayo and Froehlich, 2012, *Ch. cyanoatria* Iturralde and Leal-Zanchet, 2019, *Ch. longivesicula* Iturralde and Leal-Zanchet, 2019, *Ch. pucupucu* Carbayo et al., 2018 and the herein described *Ch. onae* Lago-Barcia and Carbayo sp. nov., *Ch riutortae* Lago-Barcia and Carbayo sp. nov. and *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. However, the general aspect of *Ch. eudoxiae* Silva and Carbayo, sp. nov. is lighter. Moreover, only *Ch. eudoxiae* Silva and Carbayo, sp. nov. and *Ch. albonigra* lack the cephalic glandular cushions among all species of the genus, with the latter having a different, black-striped dorsum.

With respect to the internal morphology, *Ch. eudoxiae* Silva and Carbayo sp. nov. is similar to *Ch. albonigra*, *Ch. tristriata*, *Ch. bocaina*, *Ch. riutortae* Lago-Barcia and Carbayo sp. nov., *Ch. claudioi* Lago-Barcia and Carbayo sp. nov., and *Ch. onae* Lago-Barcia and Carbayo sp. nov. in that the prostatic vesicle is extrabulbar and it is lacking a penis papilla. However, in the latter four species an extrabulbar portion of the prostatic vesicle is dish-shaped, whereas it is different in *Ch. eudoxiae* Silva and Carbayo sp. nov., *Ch. tristriata*, and *Ch. albonigra*. *Ch. eudoxia* sp. nov. is distinguished from *Ch. tristriata* in the relatively compact copulatory apparatus of the latter, and from *Ch. albonigra* in that the copulatory apparatus in this species is relatively longer, the paired portions of the prostatic vesicle are shorter, and the common glandular ovovitelline duct is relatively shorter.

Choeradoplana claudioi Lago-Barcia and Carbayo sp. nov.

Material examined. All specimens were collected in Reserva Biológica Augusto Ruschi, Santa Teresa, State of Espírito Santo, Brazil (-19.8891, -40.5459) by F. Carbayo and co-

workers, May 27-29th, 2008; Holotype MZUSP PL 1156 (field code, F2424), sexually mature: transverse sections of the cephalic region on 6 slides; horizontal sections of a portion behind the cephalic region on 4 slides; sagittal sections of the ovarian region on 4 slides; transverse sections of the pre-pharyngeal region on 4 slides; sagittal sections of the pharynx and copulatory apparatus on 11 slides. Paratype MZUSP PL 1157 (field code, F2510), sexually mature: sagittal sections of the pharynx and copulatory apparatus on 10 slides. The ovarian region was lost.

Distribution. Only known from the type locality, Reserva Biológica Augusto Ruschi, Santa Teresa, State of Espírito Santo, Brazil.

Etymology. The specific epithet honors Prof. Claudio Gilberto Froehlich for his contributions to the knowledge of the Neotropical land planarians.

Diagnosis. Choeradoplana species with a golden yellow ground color, with scattered sepia brown speckles on the whole dorsal surface, except for the anterior, greyish extremity. The extrabulbar portion of the prostatic vesicle is dish-shaped. The female genital atrium is compressed dorso-ventrally and partially positioned below the distal section of the male atrium.

Description. Preserved specimens measure 24.0-36.5 mm in length and 2.5-3.0 mm in width (n=2) (Fig. 14A). The body is slender and subcylindrical. The cephalic region is differentiated from the remaining body by a ‘neck’, laterally dilated and rolled up so that the ventral surface provided with glandular cushions faces out; the posterior extremity is pointed. The creeping sole is as wide as 75% (F2424) of the body width at the pre-pharyngeal region. The mouth is positioned at a distance from the anterior extremity equal to 50% of the body length, and the gonopore is at 60%.

The dorsal coloration of the live specimens consists of a golden yellow (RAL 1004) ground color, with scattered sepia brown (RAL 8014) speckles on the whole dorsal surface, except for the anterior, greyish extremity (Fig. 14A). The ventral coloration is golden yellow.

Its eyes are devoid of halos and are formed by a one-pigmented cup of 60 μm in diameter. Eyes are absent in the very anterior extremity of the body equivalent to more or less 1% of the body length. The eyes are distributed marginally in a row of 2 or 3 eyes along the first 4.5 mm (or 12% of body length), then they are arranged in a single marginal row until the posterior end.

The sensory pits are 15 μm deep, and are distributed ventro-laterally in a uniserial row, only starting at approximately the equivalent to 1% of body length. The ventral epithelium of the ovarian region was lost and sensory pits are absent in the pre-pharyngeal region.

The cutaneous musculature of the pre-pharyngeal region consists of a subepithelial circular muscle followed by a diagonal layer with decussate fibers, and a strong longitudinal muscle organized in bundles (Fig. 14B). This longitudinal muscle is 95 μm thick dorsally; it is ventrally divided into a normal, 15 μm thick muscle organized in bundles with 5-12 fibers each, and a 45 μm thick muscle sunken into the parenchyma constituted of bundles with 6-17 fibers each. The relative thickness of the cutaneous muscle coat is 16% (measurements from animal F2424 which has the best histological sections).

In the pre-pharyngeal region, a dorsal decussate muscle (25 μm thick), transverse supraintestinal muscle (25 μm), and transverse subintestinal muscle (15 μm) (n=1) (Fig. 14B).

The cutaneous and parenchymal musculature is organized in the cephalic region as in *Ch. iheringi* (Fig. 14C). The muscle retractor of the head is delta-shaped in a cross-section along 1.8 mm (or 5% of body length, F2424) from behind, 1.3 mm (or 4%, F2424) of the anterior extremity of the body (Fig. 14C), and its thickness equals 36% of the height of the cephalic region. The *Muskelgeflecht* (Graff, 1899) is 190 μm thick (32% of body height). The subneural parenchymal muscle consists of scattered transverse fibers. The glandular cushions are composed of numerous rhabditogen cells (Figs. 14C).

The mouth is located in the middle of the pharyngeal pouch (Fig. 14D). The pharynx is cylindrical-to-bell-shaped, with its dorsal insertion approximately at the mouth level. An esophagus is absent. The pharyngeal pouch is lined with a non-ciliated, low epithelium underlain by a thin layer of circular muscle with interspersed

longitudinal fibers (11-12 µm thick, n=2). The outer pharyngeal epithelium is flat, ciliated and underlain by circular muscle (40-48 µm thick, n=2) with interspersed longitudinal fibers ectally. The inner pharyngeal epithelium is flat, ciliated, and underlain by a thin circular muscle (48-50 µm, n=2). The pharynx presents numerous xanthophil, erythrophil and cyanophil gland cells.

The testes are mature, dorsal, arranged in multiple median rows between the supraintestinal transverse parenchymal muscle and the intestinal diverticula (Fig. 14B). They extend from the level of the ovaries (i.e. 7.7 mm behind the anterior extremity of the body, or 21% of body length, holotype F2424) to the root of the pharynx (48%). Sperm ducts run immediately above the subintestinal parechymatic muscle layer. In their distal portion, they open into the respective branch of the prostatic vesicle (Figs. 15A-C). The prostatic vesicle is divided into two differentiated halves (Fig. 15D). The anterior half is extrabulbar and constituted by the two widened and rounded branches opening into a broadened, dish-shaped section located above the paired portion. The posterior half is intrabulbar, dilated canal oriented dorso-posteriorly. The paired portion is lined with a cuboidal-to-columnar, ciliated epithelium, which is pierced by numerous gland cells producing fine erythrophil granules. The columnar epithelium of the dish-shaped portion is pierced by very numerous gland cells producing erythrophil gross granules (1-2 um), and by two types of scarce gland cells producing fine, erythrophil and xanthophil granules, respectively (Fig. 15D). The posterior half is lined by a columnar, ciliated epithelium with a sinuous surface which is pierced by gland cells producing erythrophil granules along its whole length, and additionally a low number of gland cells producing xanthophil granules in its distal portion. The lining epithelium of the anterior half of the prostatic vesicle is coated by a 28-30 µm thick (n=2) circular muscle; the posterior half is coated by a 1 µm thick circular muscle, followed by a 22-25 µm thick (n=2) longitudinal muscle. The extrabulbar portion of the prostatic vesicle is coated by additional muscle fibers attaching it to the common muscle coat (Figs. 15A-C). The opening of the prostatic vesicle into the antero-dorsal region of the male atrium is wide, without an ejaculatory duct or penis papilla (Figs. 15A-C).

The male atrium is approximately 6 times longer than the female atrium, and divided into a dorsal, anterior narrow third, slightly folded, and a distal 2/3rd portion with some smaller folds. A main, very large, oblique fold on each side of the body

extends behind the gonopore level and over the female atrium (Fig. 15E). The male atrium is lined by a cuboidal, non-ciliated epithelium, and is underlain by a 30-60µm-thick (n=2) mixed layer of circular muscle with numerous interspersed longitudinal fibers. The whole atrium receives two types of abundant gland cells producing erythrophil and cyanophil fine granules, respectively, and a third type of gland cells producing amorphous xanthophil secretion in the proximal third of the atrium.

The ovaries are mature, very elongated and placed above the ventral nerve plate at a distance from anterior tip of the body equal to 21% of body length (7.7 mm from anterior tip) (holotype F2424, Fig. 15E). They present an anterior, ovoid section, 300 µm in length (F2424), and a posterior, 600 µm (F2424) long narrow section. Ovovitelline ducts emerge from the lateral aspect of the ovoid section of the ovaries and run ventrally. Lateral to the posterior section of the female atrium, the ovovitelline ducts run medially and dorsally, then unite posteriorly to the female atrium (Fig. 13A, 15B and 15C). The common glandular ovovitelline duct is 45-50 µm in length (n=2) and runs ventro-anteriorly to communicate with the female genital canal. This canal runs slightly downwards and anteriorly, subsequently penetrates the common muscle coat to open into the female atrium. The female genital canal is lined by a cuboidal, ciliated epithelium.

The female atrium is dorso-ventrally compressed and wider towards the gonopore canal. It is placed below the posterior section of the male atrium (Fig. 15F), and is lined with a cuboidal non-ciliated epithelium. This epithelium is pierced by gland cells producing fine xanthophil granules. The lining epithelium of the female atrium is underlain by a 37 µm thick (n=2) layer of mixed circular and longitudinal muscle fibers.

The common muscle coat is a very dense layer composed by variously oriented muscle fibers. The length:height ratio of the copulatory apparatus enveloped by the common muscle coat ranges between 2.5-2.8:1.

Remarks

Ch. claudioi Lago-Barcia and Carbayo sp. nov. externally differs from most congeners in that the dorsum is composed of a light ground color evenly covered with brown spots. However, this color pattern is so similar to *Ch. abaiba*, *Ch. agua*, *Ch.*

banga, *Ch. iheringi*, and *Ch. pucupucu* that *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. that it cannot be confidently distinguished from them.

With respect to the internal morphology, *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. can be differentiated from most *Choeradoplana* species by the dish-shaped portion of the extrabulbar region of the prostatic vesicle. This attribute is only shared with *Ch. onae* Lago-Barcia and Carbayo sp. nov., *Ch. riutortae* Lago-Barcia and *Carbayo* sp. nov., and *Ch. bocaina*. However, the female genital atrium is compressed dorso-ventrally and partially positioned below the distal section of the male atrium, which readily distinguishes *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. from these three other species.

Choeradoplana onae Lago-Barcia and Carbayo sp. nov.

Synonymy
Choeradoplana sp. in Álvarez-Presas et al., 2014

Material examined. All specimens collected in the Reserva Biológica Augusto Ruschi, Santa Teresa, State of Espírito Santo, Brazil (-19.88, -40.54) by F. Carbayo and co-workers, May 25-27th, 2008; Holotype MZUSP PL 2270 (field code, F2414), transverse sections of the cephalic region on 8 slides; horizontal sections of the portion behind the cephalic region on 5 slides; sagittal sections of the ovarian region on 12 slides; horizontal sections of the testes on 10 slides; transverse sections of the pre-pharyngeal region on 9 slides; sagittal sections of the pharynx and copulatory apparatus on 12 slides; Paratype MZUSP PL 2267 (field code, F2230), transverse sections of the cephalic region on 8 slides; sagittal sections of the pharynx and copulatory apparatus on 9 slides; Paratype MZUSP PL 2268 (field code, F2281), sagittal sections of the pharynx and copulatory apparatus on 12 slides. Paratype MZUSP PL 2269 (field code, F2310), transverse sections of the cephalic region on 12 slides; horizontal sections of the ovarian region on 8 slides.

Distribution. Only known from the type locality, Reserva Biológica Augusto Ruschi, Santa Teresa, State of Espírito Santo, Brazil.

Etymology. The name onae is the affectionate nickname of the biologist Marta Álvarez-Presas (Bristol University). The specific epithet honors her for her contributions to understanding the systematics of free-living flatworms.

Diagnosis. Choeradoplana species with a light ivory ground color and a wide sepia brown median band. The extrabulbar region of the prostatic vesicle has a dish-shaped portion. The copulatory apparatus is 3.8 times longer than its height. The male atrium has 4-6 main folds.

Description. External aspect. Preserved specimens range between 41-44.5 mm in length and 3-4 mm (n=4) in width (Fig. 16A). The body is slender and subcylindrical. The cephalic region is differentiated from the remaining body by a 'neck' and laterally dilated. This region is rolled up so that the ventral surface provided with two prominent glandular cushions is facing out when alive (Fig. 16A and C); the posterior extremity is pointed. The creeping sole is as wide as 85-87% of body width at the pre-pharyngeal region (n=4). The mouth is positioned at a distance from the anterior extremity equal to 51% of body length, and the gonopore is 61% (paratype F2230).

The dorsal coloration of live specimens consist of a light ivory (RAL 1015) ground color (Fig. 16A), covered on a wide median band with sepia brown pigment (RAL 8014), except for irregular clear spots with the ground color exposed. The bordering line of the band merging with the ground color on the sides is irregular with large sepia brown spots. The curled anterior extremity is red orange (RAL 2001). The ventral surface is red orange in the cephalic region, and light grey (RAL 7035) in the rest of body (Fig. 16B).

The eyes are devoid of halos, and formed by a one-pigmented cup of 60 μm in diameter. Eyes are absent in the very anterior extremity of the body equivalent to 1% of the body length (n=1). Eyes behind the anterior tip are distributed marginally in a row of 2 or 3 eyes and extend along the entire body until the posterior end (Fig. 5C).

Sensory pits are 20-25 μm deep in a uniserial ventro-lateral row, starting from 0.4 mm behind the anterior extremity, the equivalent of 1% body length to at least 80 mm from the anterior tip (20% of body length, n=1).

Rhabditogen gland cells pierce the marginal epidermis in the pre-pharyngeal region. Erythrophil granules and scarce cyanophil granules are discharged through the entire epidermis. There is no glandular margin (Fig. 16D).

The cutaneous musculature consists of a subepithelial circular muscle, followed by a diagonal layer with decussate fibers, and a strong longitudinal muscle organized in bundles (Figs. 16D). This longitudinal muscle is 90-100 μm thick dorsally, and organized in tight bundles with 32-60+ fibers each; it is ventrally divided into a normal, 30-32.5 μm thick muscle organized in bundles with 5-11 fibers each, and a 75 um thick muscle sunken into the parenchyma, and constituted of bundles with 8-27 fibers each (Fig. 16D). The relative thickness of the cutaneous muscle coat is 18-20% (n=4).

In the pre-pharyngeal region, there are three parenchymal muscles, namely a dorsal decussate muscle (40-50 μm thick), a transverse supraintestinal muscle (15 μm), and transverse subintestinal muscle (18-20 μm) (n=4) (Fig. 16D).

The cutaneous and parenchymal musculature is organized in the cephalic region as in *Ch. iheringi*. The muscle retractor of the head is delta-shaped in a cross-section along 2.5 mm (or 6% of body length) from behind, 0.9 mm (or 2%) anterior extremity of the body (Fig. 16E), and its thickness equals 19% of the height of the cephalic region. The *Muskelgeflecht* (Graff, 1899) is 160-180 μm thick (23% of body height). The subneural parenchymal muscle consists of a number of transverse fibers; this muscle is weak in the ovarian region. Glandular cushions are composed of very numerous rhabditogen cells (Fig. 16E).

The mouth is located in the middle of the pharyngeal pouch (n=4) (Figs. 17A-B). The pharynx is bell-shaped with its dorsal insertion at mouth level (n=4). The esophagus is as long as 15% of the pharyngeal length. The pharyngeal pouch is lined with a non-ciliated, low epithelium underlain by a one-fiber thick longitudinal muscle followed by a 10 μm thick circular muscle. The outer pharyngeal epithelium is flat, ciliated, and underlain by a 5 μm thick longitudinal muscle followed by a 15 μm thick circular muscle. The inner pharyngeal epithelium is flat and ciliated, and is underlain by a mixed

circular muscle with longitudinal fibers (80 µm thick). The pharynx has numerous interspersed erythrophil and xanthophil gland cells.

The testes are mature, dorsally located under the supraintestinal transverse parenchymal muscle, placed between the intestinal diverticula. They extend from 13.2 mm (32% of body length, holotype F2414) from the anterior extremity to 0.2 mm of the root of the pharynx (63%, holotype F2414). Sperm ducts bend dorsally and medially immediately above the subintestinal parechymatic muscle layer to open into the respective dilated branch of the prostatic vesicle. The prostatic vesicle is divided into two differentiated halves (Fig. 17C). The anterior half is extrabulbar and proximally presents a dilated and paired tubular portion oriented vertically which opens into a broadened, dish-shaped section located above the paired portion. This anterior half is lined by a columnar-to-cuboidal epithelium that is pierced by gland cells producing xanthophil granules. These gland cells are much more abundant in the dish-shaped portion and present a strongly reddish appearance; the ventral face and the border of this dish-shaped section of the prostatic vesicle is also pierced by gland cells producing cyanophil granules. The posterior half is an intrabulbar dilated canal oriented dorso-posteriorly. It is lined by a columnar epithelium with a sinuous surface that is pierced by gland cells producing cyanophil granules along its whole length and additionally gland cells producing xanthophil granules in its distal portion. The lining epithelium of the anterior half of prostatic vesicle is coated by an 18-20 µm thick circular muscle layer, while it is coated by a 1 µm thick circular muscle in the posterior half, followed by a 15 µm thick longitudinal muscle (n=4). The extrabulbar portion of the prostatic vesicle is coated by additional muscle fibers attaching it to the common muscle coat (Fig. 17D). The opening of the prostatic vesicle into the antero-dorsal region of the male atrium is wide, without an ejaculatory duct or penis papilla (Figs. 18A-C).

The male atrium is long, five times as long as the female atrium, with the same height along its length and 4-6 large transverse folds narrowing its lumen. The male atrium is lined by a cuboidal, non-ciliated epithelium, and is underlain by a 40-70µm-thick circular muscle with numerous interspersed longitudinal fibers (n=4). The proximal two thirds of the atrium receive two types of abundant gland cells producing xanthophil and erythrophil granules, respectively, and a third type of scarce gland cells producing amorphous xanthophil secretion; the distal third of the male atrium receives

abundant gland cells producing erythrophil granules. The sub-apical portion of the cells of the lining epithelium of this distal third contains xanthophil granules.

The ovaries are mature, ovoid and 250 µm in length, placed above the ventral nerve plate and at a distance from the anterior tip of the body equal to 28% of body length (11.8 mm from the anterior tip) (n=1). Ovovitelline ducts emerge from the dorso-lateral aspect of the ovaries and run ventrally. Ovovitelline ducts run medially and dorsally lateral to the posterior section of the female atrium, then unite above the postero-dorsal section of the female atrium (Figs. 18A-C). The common glandular ovovitelline duct length ranges between 25-150 µm in length (n=4) and runs ventrally or ventro-posteriorly to communicate with the female genital canal. This canal runs downwards, and subsequently penetrates the common muscle coat to open into the posterior section of the female atrium. The genital canal is lined by a cuboidal, ciliated epithelium, and the sub-apical portion of its lining cells is stained reddish.

The female atrium is funnel-shaped, and is lined with a 50 µm high epithelium, which is pierced by gland cells producing fine erythrophil granules. The subapical portion of the lining cells contains xanthophil granules. The lining epithelium of the female atrium is underlain by a 1-fiber-thick longitudinal muscle, followed by a 10 µm thick layer of decussate muscle fibers. Paratype F2281 presents a spermatophore at the entrance of the gonopore canal (Fig. 18D) and its female atrium is smaller than that of the remaining specimens.

The common muscle coat is a very dense layer composed by variously oriented muscle fibers. The length:height ratio of the copulatory apparatus enveloped by the common muscle coat ranges between 2.5-3.3:1 (n=3).

Remarks

The species described herein matches all diagnostic characteristics of *Choeradoplana*. As reported for *Ch. claudioi* Lago-Barcia and Carbayo sp. nov., *Ch. onae* Lago-Barcia and Carbayo sp. nov. only confounds with *Ch. abaiba*, *Ch. agua*, *Ch. banga*, *Ch. iheringi*, *Ch.claudioi* Lago-Barcia and Carbayo sp. nov., and *Ch. pucupucu* in the body color. The great similarity between them hinders confident identification. However, none of them present the prominent cushions found in this species with a red-orange color.

With respect to the internal morphology, *Ch. onae* Lago-Barcia and Carbayo sp. nov. only compares with *Ch. riutortae* Lago-Barcia and Carbayo sp. nov. and *Ch. bocaina* in that they also present a dish-shaped prostatic vesicle. However, the length:height ratio of the copulatory apparatus in these species is 2.6:1 (vs. 3.8:1 in *Ch. onae* Lago-Barcia and Carbayo sp. nov.); the male atrium:female atrium ratio in *Ch. bocaina* and *Ch. riutortae* Lago-Barcia and Carbayo sp. nov. ratio ranges between 1:1-3:1 (Carbayo and E. M. Froehlich, 2012), whereas it is ~5:1 in *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. and *Ch. onae* Lago-Barcia and Carbayo sp. nov., and the male atrium presents 1-2 large folds (vs. 4-6 in *Ch. onae* Lago-Barcia and Carbayo sp. nov.).

Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov.

Material examined. All specimens were collected in the Parque Nacional da Serra dos Orgãos, Teresópolis, State of Rio de Janeiro, Brazil (-22.48, -43.06) by F. Carbayo and co-workers, January 6th, 2010. Holotype MZUSP 2274 (field code, F4218), transverse sections of the cephalic region on 5 slides; horizontal sections of the portion behind the cephalic region on 6 slides; sagittal sections of ovarian region on 6 slides; horizontal sections of the testes on 4 slides; transverse sections of the pre-pharyngeal region on 7 slides; sagittal sections of the pharynx and copulatory apparatus on 9 slides. Paratype MZUSP PL 1174 (field code, F4217), transverse sections of the cephalic region on 9 slides; horizontal sections of the ovarian region on 7 slides; transverse sections of the pre-pharyngeal region on 8 slides; sagittal sections of the pharynx and copulatory apparatus on 12 slides. Paratype MZUSP PL 2275 (field code, F4261), transverse sections of the pre-pharyngeal region on 16 slides; sagittal sections of the pharynx and copulatory apparatus on 27 slides.

Distribution. Only known from the type locality, Parque Nacional da Serra dos Orgãos, municipality of Teresópolis, State of Rio de Janeiro, Brazil.

Etymology. The specific epithet honors Prof. Marta Riutort for her contributions to understanding the evolution of flatworms.

Diagnosis. Choeradoplana species with a light ivory ground color covered by numerous sepia brown spots except for the anterior extremity which is red orange. The ventral surface is pale orange in the cephalic region, and light grey in the rest of the body. Part of the longitudinal cutaneous musculature is sunken in the parenchyma of the ventral side. The prostatic vesicle has a paired extrabulbar dish-shaped portion, and an elongated intrabulbar portion with a sinuouse epithelium. It has a short copulatory apparatus (the length:height ratio of the copulatory apparatus is 2.6:1). The male atrium presents the same size as the female atrium.

Description. The preserved animals measure between 37-42 mm in length and 2.5-3 mm in width (n=3) (Fig. 19A). The body is slender and subcylindrical. The cephalic region is differentiated from the remaining body by a 'neck', laterally dilated and rolled up so that the ventral surface, provided with prominent glandular cushions, is facing out (Figs. 19A-C); the posterior extremity is pointed. The creeping sole is as wide as 72-75% of body width in the pre-pharyngeal region (n=3). The mouth is positioned at a distance from the anterior extremity equal to 63-67% of body length, and the gonopore is 72-78% (n=3).

The dorsal coloration in live specimens consists of a light ivory (RAL 1015) ground color, with numerous sepia brown (RAL 8014) spots which are more (F4218) or less (F4217) merged with each other, with the latter situation presenting a somewhat homogeneous aspect. A midline with the ground color may extend along the body length (paratype F4217) or is restricted to the anterior region of the body (paratype F4261). The spots extend to the body sides, where they are scattered so as to create an irregular bordering line, followed by the ground color of the sides of the body. A curled anterior extremity is red orange (RAL 2001). The ventral surface is pale red orange in the cephalic region, and light grey (RAL 7035) in the rest of the body (Fig. 19B).

The eyes are formed by a one-pigmented cup of 46-50 μm in diameter. There are no halos around them. Eyes are absent in the very anterior extremity of the body equivalent to 1% of the body length (F4218). Eyes behind the anterior tip are distributed marginally in a row of 2 or 3 eyes and extend along the entire body until the posterior extremity.

Sensory pits are 15 μm deep, distributed ventro-laterally in a uniserial row initiating 0.3 mm behind the anterior extremity (the equivalent of 1% of the body length in paratype F4217), and from the very anterior tip in holotype F4218.

In the pre-pharyngeal region, very abundant rhabditogen gland cells pierce the dorsal and marginal epidermis. These types of cells are scarce on the ventral epidermis; instead, there are gland cells producing erythrophil granules and scarce gland cells secreting cyanophil granules. There is no glandular margin (Fig. 19D).

The cutaneous musculature of the pre-pharyngeal region consists of a subepithelial circular muscle, followed by a diagonal layer with decussate fibers, and a longitudinal muscle organized in bundles (Figs. 19D). This longitudinal muscle is 80-100 μm thick dorsally and organized in tight bundles with ~60-~110 fibers each; it is ventrally divided into a normal, 28-30 μm thick muscle organized in bundles with 10-27 fibers each, and a 55-65 μm thick muscle sunken into the parenchyma and constituted of bundles with 18-40 fibers each (Fig. 19D). The relative thickness of the cutaneous muscle coat is 22-25% (n=3).

There are three parenchymal muscles in the pre-pharyngeal region, namely a dorsal decussate muscle (46-50 μm thick), transverse supraintestinal muscle (25-30 μm), and transverse subintestinal muscle (70-75 μm) (n=3) (Fig. 19D).

The cutaneous and parenchymal musculature is organized in the cephalic region as in *Ch. iheringi*. A portion of the muscle retractor of the head is delta-shaped in a cross-section and ranges between 2-5 mm (or 5-14% of body length) from behind, 1-1.3 mm (2-3%) of the anterior extremity of the body (Fig. 19E), and its thickness equals 36% of the height of the cephalic region. The *Muskelgeflecht* (Graff, 1899) is 200-210 μm thick (30% of body height). The subneural parenchymal muscle consists of transverse fibers. Glandular cushions are composed of very numerous rhabditogen cells and scarce gland cells produce erythrophil granules (Figs. 19E).

The mouth is located in the middle of the pharyngeal pouch (n=3) (Fig. 20A). The pharynx is bell-shaped, and has its dorsal insertion shifted posteriorly with the equivalent to 44% of the pharynx length. The esophagus length is 20% of the pharyngeal length. The pharyngeal pouch is lined with a non-ciliated, low epithelium underlain by a one-fiber-thick layer of longitudinal muscle followed by 20 μm thick layer of circular muscle. The outer pharyngeal epithelium (Fig. 20A) is flat, ciliated, and

underlain by a one-fiber-thick longitudinal muscle, followed by a 15 µm thick muscle with some longitudinal fibers interspersed. The inner pharyngeal epithelium is flat, ciliated, and underlain by a mixed layer of circular muscle with longitudinal muscle (75 µm thick). The pharynx presents numerous erythrophil and xanthophil gland cells interspersed.

The testes are mature and dorsally located under the supraintestinal transverse muscle layer, mostly placed between the intestinal diverticula. They extend from 12.7 mm (30% of body length, holotype F4218) of the anterior extremity of the body to 0.5 mm before the root of the pharynx. Sperm ducts run immediately above the subintestinal parechymatic muscle layer. The sperm ducts bend dorsally close to the copulatory apparatus, and subsequently penetrate the ventral anterior region of the common muscle coat to open into the respective dilated branch of the prostatic vesicle (Fig. 20B). The prostatic vesicle is divided into two differentiated halves; the anterior half proximally presents a dilated and paired portion oriented vertically which opens into a broadened, dish-shaped section located above the paired portion (Fig. 20B). This anterior half is extrabulbar and lined by a columnar-to-cuboidal epithelium which is pierced by gland cells producing xanthophil granules. These gland cells are much more abundant in the dish-shaped portion, and present a reddish appearance; the border of this dish-shaped section of the prostatic vesicle is also pierced by gland cells producing cyanophil granules. The posterior half is intrabulbar, and is a straight tube running postero-dorsally to open into the anterior region of the male atrium. This half is lined by a columnar epithelium with a sinuous surface which is pierced along its whole length by gland cells producing cyanophil granules; additionally, gland cells producing xanthophil granules pierce its distal portion. The lining epithelium of the anterior half of the prostatic vesicle is coated by a 20 µm thick circular muscle; the posterior half is coated by a 1 µm thick circular muscle, followed by a 15 µm thick longitudinal muscle. The male atrium is the same size as the female atrium, and is divided into a proximal, narrow half and a distal, dilated half with some small folds (Figs. 21A-B and 22A-B).

The male atrium is lined by a cuboidal, non-ciliated epithelium, and underlain by a 45-80 µm thick layer of circular muscle with numerous interspersed longitudinal fibers (n=3). The proximal half of the atrium receives two types of gland cells, one producing erythrophil granules, and a second type of scarce gland cells producing

xanthophil granules; the distal half of the male atrium receives abundant gland cells producing xanthophil granules and the sub-apical portion of the cells of the lining epithelium contains xanthophil granules. The extrabulbar portion of the prostatic vesicle is coated by additional muscle fibers attaching it to the common muscle coat (Figs. 21A-B and 22A-B).

The ovaries are mature, ovoid, 190 µm in length, and placed above the ventral nerve plate, and at a distance from the anterior body tip equal to 27% of body length (11.5 mm from anterior tip) (holotype F4218). Ovovitelline ducts emerge from the dorso-lateral aspect of the ovaries and run above the ventral nerve plate. Lateral to the female atrium, the ovovitelline ducts bend medianly and dorsally, then unite above the postero-dorsal section of the female atrium (Figs. 21A-B and 22A-B). The common glandular ovovitelline duct is outside the common muscle coat, and runs posteriorly, progressively inclining to the ventral side to communicate with the posterior section of the female atrium.

The female atrium is divided into a dilated canal running ventro-anteriorly and outside the common muscle coat, and a distal, funnel-shaped half is widely communicated with the male atrium (Figs. 21A-B and 22A-B). The female atrium is lined with a 35 µm high epithelium. This epithelium is pierced by gland cells producing fine erythrophil granules. The subapical portion of lining cells of the distal half of the atrium contains xanthophil granules. The lining epithelium of the female atrium is underlain by a layer of mixed circular and longitudinal fibers 10 µm high.

The common muscle coat is a very dense layer composed by densely packed muscle fibers variously oriented (Figs. 21A-B and 22A-B). The length:height ratio of the copulatory apparatus enveloped by the common muscle coat ranges between 2.2-2.7:1 (n=3).

Remarks

Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov. matches all diagnostic characteristics of *Choeradoplana*. The external dorsal coloration resembles 11 species inside the genus with the ground color being brownish with dark black or dark brown spots over it, namely *Choeradoplana abaiba*, *Ch. agua*, *Ch. banga*, *Ch. benyai*, *Ch. bocaina*, *Ch. cyanoatria*, *Ch. longivesicula*, *Ch. pucupucu* and the herein

described *Ch. onae* Lago-Barcia and Carbayo sp. nov., *Ch. eudoxiae* Silva and Carbayo, sp. nov. and *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. However, none of them present the prominent cushions found in this species, nor the conspicuous red-orange coloration of the cephalic region.

With respect to the internal morphology, *Ch. riutortae* Lago-Barcia and Carbayo sp. nov. is only similar to *Ch. onae* Lago-Barcia and Carbayo sp. nov., *Ch. bocaina* and *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. in that the extrabulbar section of the prostatic vesicle is dish-shaped. However, the female atrium in *Ch. claudioi* Lago-Barcia and Carbayo sp. nov. is partially below the male one (vs. behind, in *Ch. riutortae* Lago-Barcia and Carbayo sp. nov.), whereas the male atrium in *Ch. onae* Lago-Barcia and Carbayo sp. nov. has the same height along its length, (vs. a proximal, narrow half, and a distal, widened half). Finally, the male atrium in *Ch. bocaina* is three times as long as the female, whereas this ratio is 1.2 in *Ch. riutortae* Lago-Barcia and Carbayo sp. nov.

Discussion

The monophyletism of the *Choeradoplana* genus was first demonstrated by Carbayo et al. (2013), and subsequently by Lemos et al., (2014) and Carbayo et al. (2018) with additional terminals and species. All species were recovered as monophyletic, perhaps with the exception of *Ch. bocaina*. The clade which includes the three type specimens of *Ch. bocaina* also houses two individuals not studied morphologically which were collected in the Reserva Biológica Augusto Ruschi, ES (500 km distance from the type locality). These two individuals are terminals with long internal branches. In agreement with this view, Carbayo et al. (2018) found uneven molecular delimitations of species depending on the method applied.

Interestingly, although the species interrelationships are poorly supported, the species composition of the two large clades is similar to the phylogeny inferred from five mitochondrial and nuclear concatenated genes by Carbayo et al. (2018).

Choeradoplana is one among the few geoplanid genera which can be recognized through the body shape. The cephalic region in this genus is typically rolled up and the ventral surface of it is provided with glandular cushions, separated by a longitudinal

groove. However, as shown above, the cephalic region of *Ch. albonigra* and *Ch. eudoxiae* Silva and Carbayo, sp. nov. lack the glandular cushions and it is not expanded latero-laterally. In this respect, these two species cannot be distinguished from *Cephaloflexa*. Moreover, the anterior third of the body in *Ch. albonigra* narrows very gradually as in *Cephaloflexa*. Therefore, assignment to a genus must be based on internal aspects of these two species.

Another interesting observation is the distribution of the sensory pits. Following the diagnosis of *Choeradoplana*, these pits occur along a variable portion of the anterior region of the body, but they are absent in the apex (a feature also shared with *Cephaloflexa*). However, sensory pits in *Ch. riutortae* Lago-Barcia and Carbayo sp. nov. contour the anterior extremity in one of the two examined specimens. Since the sensory pits in the apex are not present in all specimens, it can be interpreted as a deviant individual situation.

The diagnosis of *Choeradoplana* was emended by Froehlich (1955), Ogren and Kawakatsu (1990), Carbayo and E. M. Froehlich (2012) and as a consequence of the morphological variations reported in this paper herein we propose to emend the genus as follows (emendation underlined):

Geoplaninae of elongated subcylindrical body. The cephalic region is kept rolled up and backwards; this region usually presents two glandular cushions, ventrally separated by a longitudinal groove. The cephalic region may be latero-laterally dilated giving rise to a “neck” which differentiates this region from the remaining body. Eyes absent in the apex. Sensory pits absent in the apex. Broad creeping sole, more than one-third of body width. Strong cutaneous longitudinal muscles partially sunken into the parenchyma, exclusively ventrally or, more rarely, ventrally and dorsally too. Anteriorly all sunken ventral longitudinal fibers medianly concentrated, constituting the retractor unroller of the cephalic extremity. Bodies of rhabditogen cells located between the retractor and the epidermis. Common glandular ovovitelline duct approaching female genital canal dorsally from anterior direction, more rarely approaching behind the female atrium from the ventral direction.

The six species studied in this paper (except *Ch. albonigra* and *Ch. eudoxiae* Silva and Carbayo, sp. nov.) present the external and internal characteristics of the *Choeradoplana* genus. The morphological diagnostic characteristics of this genus are

remarkably heterogeneous in attributes found to be stable within other geoplanin genera. In addition to the variable shape of the cephalic region (discussed above), the longitudinal dorsal cutaneous musculature in *Choeradoplana* can be sunken (*Ch. gladismariae* Carbayo and Froehlich, 2012), a penis papilla can be present (*Ch. crassiphalla*, *Ch. benyai*, *Ch. marthae*), an inverted penis may also occur (*Ch. minima* Lemos and Leal-Znachet, 2014), the prostatic vesicle may be intrabulbar (several species), the female genital canal can approach the female atrium behind it from the ventral direction (*Ch. banga*). Thus, we have increased the number of morphological variations seen in the genus in the present study, with the most remarkable being, (i) the ventral glandular cushions may be reduced or even absent, as in *Ch. albonigra* and *Ch. eudoxiae* Silva and Carbayo sp. nov.; (ii) the anterior third of the body may become progressively thinner towards the anterior tip, as in *Ch. albonigra*. Therefore, one cannot trust the shape of the cephalic region anymore for assigning a species with the head rolled-up to a genus. Instead, histological sections should be examined.

Despite the great variability in the diagnostic features, the genus can still be diagnosed by the following two exclusive attributes among Geoplanids: muscle retractor of the cephalic region delta-shaped in the cross-section; and bodies of rhabditogen cells piercing the cephalic ventral epidermis are located between the retractor and the epidermis.

Acknowledgements

Dieter Fiege (Museum der Senckenbergischen Naturforschenden Gesellschaft in Frankfurt, Germany) kindly sent the holotype of C. albonigra on loan. ICMBio provided permit #11748-4 for the fieldwork. Ana Cristina Vasconcellos, Lucas Beltrami, and Geison Castro helped with histological sections. Marcus R. Hara and Fernando Portella de Luna Marques for their constructive comments on a previous version of the manuscript. Ana Laura Almeida is fully thanked for her help with molecular bench work. Ana María Rodríguez (University Carlos III de Madrid) is thanked for her help with the etymology, and Christopher Quinn for revision of the English text. DL-B thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq (Proc. 152971/2016-5) for a PhD fellowship. São Paulo Research Foundation (FAPESP, Process # 2019/12357-7) provided financial support to FC.

References

Álvarez-Presas MA, Carbayo F, Rozas J, Riutort M. 2011. Land planarians (Platyhelminthes) as a model organism for fine-scale phylogeographic studies: understanding patterns of biodiversity in the Brazilian Atlantic Forest hotspot. *Journal of Evolutionary Biology* 24: 887-896. https://doi.org/10.1111/j.1420-9101.2010.02220.x

Álvarez-Presas M, Sánchez-Gracia A, Carbayo F, Rozas J, Riutort M. 2014. Insights into the origin and distribution of biodiversity in the Brazilian Atlantic forest hot spot: a statistical phylogeographic study using a low-dispersal organism. *Heredity* 112: 656–665. https://doi.org/10.1038/hdy.2014.3 PMID: 24549112

Carbayo F, Leal-Zanchet AM. 2001. A new species of terrestrial planarian (Platyhelminthes: Tricladida: Terricola) from South Brazil. *Brazilian Journal of Biology* 61: 1519–6984. DOI: 10.1590/S1519-69842001000300013

Carbayo F, Leal-Zanchet AM. 2003. Two new genera of Geoplaninae (Terricola: Tricladida: Platyhelminthes) of Brazil in the light of cephalic apomorphies. *Invertebrate Systematics* 17(3): 449–468. DOI: 10.1017/S0952836901000401

Carbayo F, Froehlich EM. 2012. Three new Brazilian species of the land planarian Choeradoplana (Platyhelminthes: Tricladida: Geoplaninae), and an emendation of the genus. *Journal of Natural History* 46(19–20): 1153–1177. https://doi.org/10.1080/00222933.2012.657699

Carbayo F, Álvarez-Presas M, Olivares CT, Marques FPL, Froehlich EM, Riutort M. 2013. Molecular phylogeny of Geoplaninae (Platyhelminthes) challenges current classification: proposal of taxonomic actions. *Zoologica Scripta* 42(5): 508–528. DOI:10.1111/zsc.12019

Carbayo F, Silva MS, Riutort M, Alvarez-Presas M. 2018. Rolling into the deep of the land planarian genus Choeradoplana (Tricladida, Continenticola, Geoplanidae) taxonomy. *Organisms Diversity & Evolution* 18(2): 187–210. https://doi.org/10.1007/s13127-017-0352-4

Cason JE. 1950. A rapid one-step Mallory-Heidenhain stain for connective tissue. *Stain Technology* 25(4): 225-226. https://doi.org/10.3109/10520295009110996

Dendy A. 1894. Note on a new variety of Peripatus novae-zelandiae, Hutton. *Transactions and Proceedings of the Royal Society of New Zealand* 27: 190-191.

Du Bois-Reymond Marcus E. 1951. On south american geoplanids. *Boletim da Faculdade de Filosofia Ciências e Letras da Universidade de São Paulo, Série Zoologia* 16: 217–255. DOI: https://doi.org/10.11606/issn.2526-4877.bsffclzoologia.1951.125222

Felsenstein J. 1985. Confidence limits on phylogenies: an approach using the bootstrap. *Evolution* 39: 791–793. DOI: 10.1111/j.1558-5646.1985.tb00420.x

Froehlich CG. 1955. Sobre morfologia e taxonomia das Geoplanidae. *Boletim da Faculdade de Filosofia, Ciências e Letras. Série Zoologia* 19: 195–279. https://doi.org/10.11606/issn.2526-3382.bffclzoologia.1954.120092

Froehlich CG. 1959. On geoplanids from Brazil. *Boletins da Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo, Série Zoologia* 22: 201-265. https://doi.org/10.11606/issn.2526-3382.bffclzoologia.1959.120326

Graff L. 1896. Ueber das System und die geographische Verbreitung der Landplanarien. *Verhandlungen de Deutschen Zoologischen Gesellschaft* 6: 75-93.

Graff LV. 1899. Monographie der Turbellarien. II. Tricladida Terricola (Landplanarien). I–XII. Atlas von Achtundfünfzig Tafeln zur Monographie der Turbellarien II. Tricladida Terricola (Landplanarien). Pls I–LVIII. Wilhelm Engelmann, Leipzig, 574 pp.

Hall TA. 1999. BioEdit: A User-Friendly Biological Sequence Alignment Editor and Analysis Program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95-98.

Hurvich CM, Tsai C-L. 1989 Regression and Time Series Model Selection in Small Samples. *Biometrika* 76: 297–307. https://doi.org/10.1093/biomet/76.2.297

Iturralde GG, Leal-Zanchet AM. 2019 Why be original? Two new species of Choeradoplana resembling the type species of the genus in their external aspects (Platyhelminthes, Continenticola). *ZooKeys* 813(2): 1-19. https://doi.org/10.3897/zookeys.813.29565

Katoh K, Rozewicki J, Yamada KD. 2019. MAFFT online service: Multiple sequence alignment, interactive sequence choice and visualization. *Briefings in Bioinformatics* 20(4): 1160–1166. https://doi.org/10.1093/bib/bbx108

Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott B. 2016. PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. *Molecular biology and evolution* 34(3): 772-773. https://dx.doi.org/10.1093/molbev/msw260

Lázaro EM, Sluys R, Pala M, Stocchino GA, Baguñà J, Riutort M. 2009. Molecular barcoding and phylogeography of sexual and asexual freshwater planarians of the genus *Dugesia* in the Western Mediterranean (Platyhelminthes, Tricladida, Dugesiidae). *Molecular Phylogenetics and Evolution* 52: 835–845. https://doi.org/10.1016/j.ympev.2009.04.022

Lemos VSA, Cauduro GPB, Valiati HV, Leal-Zanchet AM. 2014. Phylogenetic relationships within the flatworm genus *Choeradoplana* Graff (Platyhelminthes: Tricladida) inferred from molecular data with the description of two new sympatric species from Araucaria moist forests. *Invertebrate Systematics* 28: 605–627. http://dx.doi.org/10.1071/IS14003

Marcus E. 1951. Turbellaria brasileiros (9). *Boletim da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo. Série Zoologia* 16: 1–217. https://doi.org/10.11606/issn.2526-4877.bsffclzoologia.1951.125221

Miller SA, Dykes DD, Polesky HF. 1988. A simple salting out procedure for extracting DNA from human nucleated cells. *Nucleic Acids Research* 16(3): 1215. https://doi: 10.1093/nar/16.3.1215

Miller MA, Pfeiffer W. Schwartz T. 2010. Creating the CIPRES Science Gateway for inference of large phylogenetic trees. In: 2010 gateway computing environments workshop (GCE) pp. 1-8. DOI: 10.1109/GCE.2010.5676129

Negrete L, Brusa F. 2012. Choeradoplana crassiphalla sp. nov. (Platyhelminthes: Tricladida: Geoplanidae): a new species of land planarian from the Atlantic Forest of Argentina. *Studies on Neotropical Fauna and Environment* 47: 227–237. https://doi:10.1080/01650521.2012.735071

Ogren RE, Kawakatsu M. 1990. Index to the species of the family Geoplanidae (Turbellaria, Tricladida, Terricola) Part I: Geoplaninae. *Bulletin of Fuji Women's College* 28(1): 79-166.

Riester A. 1938. Beiträge zur Geoplaniden-Fauna Brasiliens. *Abhandlungen der Senkenbergischen naturforschenden Gesellschaft* 441: 1–88.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP. 2012. MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539–542. https://doi.org/10.1093/sysbio/sys029

Schultze M, Müller F. 1857. Beiträge zur Kenntnis der Landplanarien, nach Mittheilungen des Dr. Fritz Müller in Brasilien und nach eigenen Untersuchungen von Dr. Max Schultze. *Abhandlungen der Naturforschenden Gesellschaft zu Halle* 4: 61-74.

Spencer WB. 1892. Land Planarians from Lord Howe Island. Part. 1. Descriptions of Species. Trans. R.S. Victoria, Tome 2, Melbourne, 42-51.

Stamatakis A. 2006. RAxML-VI-HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics* 22(21): 2688–2690. https://doi.org/10.1093/bioinformatics/btl446

Stimpson W. 1857. Prodromus descriptionis animalium evertebratorum, etc. *Proceedings of the Academy of Natural Sciences of Philadelphia* 9: 19-14.

Sunnucks P, Blacket MJ, Taylor JM, Sands CJ, Ciavaglia SA, Garrick RC, Tait NN, Rowell DM, Pavlova A. 2006. A tale of two flatties: different responses of two terrestrial flatworms to past environmental climatic fluctuations at Tallaganda in montane southeastern Australia. *Molecular Ecology* 15: 4513-4531. DOI: 10.1111/j.1365-294X.2006.03107.x

Winsor L. 1991. A new genus and species of terrestrial flatworm from the central highlands of New Caledonia (Tricladida Terricola). *Mémoires du Museum national d'histoire naturelle (Paris)* 149: 19-30.

Figures

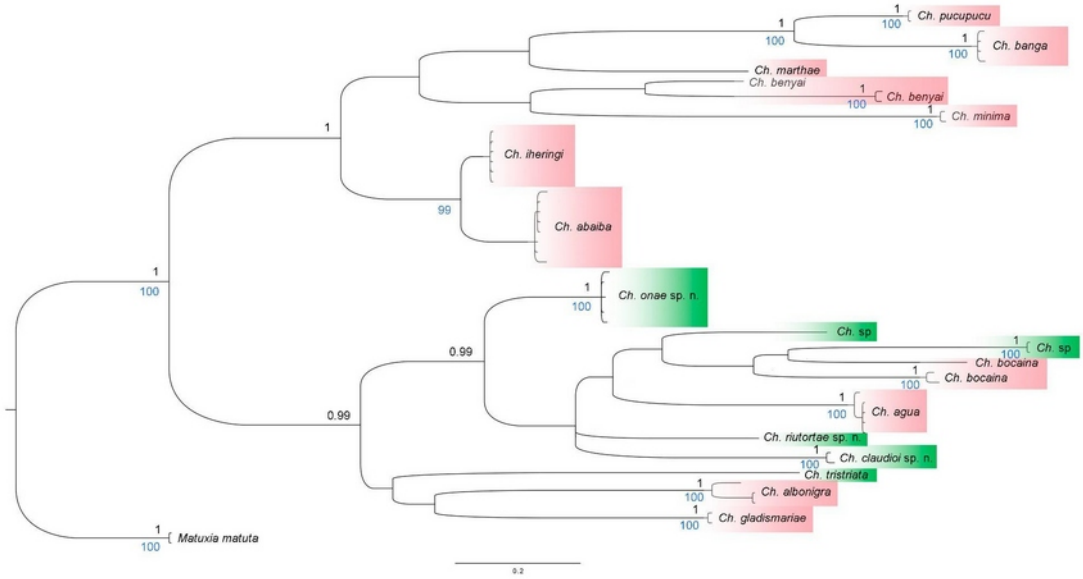


Fig. 1. Phylogenetic tree of *Choeradoplana* obtained from the COI gene by Bayesian inference. Black numbers at the nodes correspond to the posterior probability (only values above 0.99 shown) and blue numbers to Bootstrap support in the tree by maximum likelihood (only values above 95% shown). See text for details.

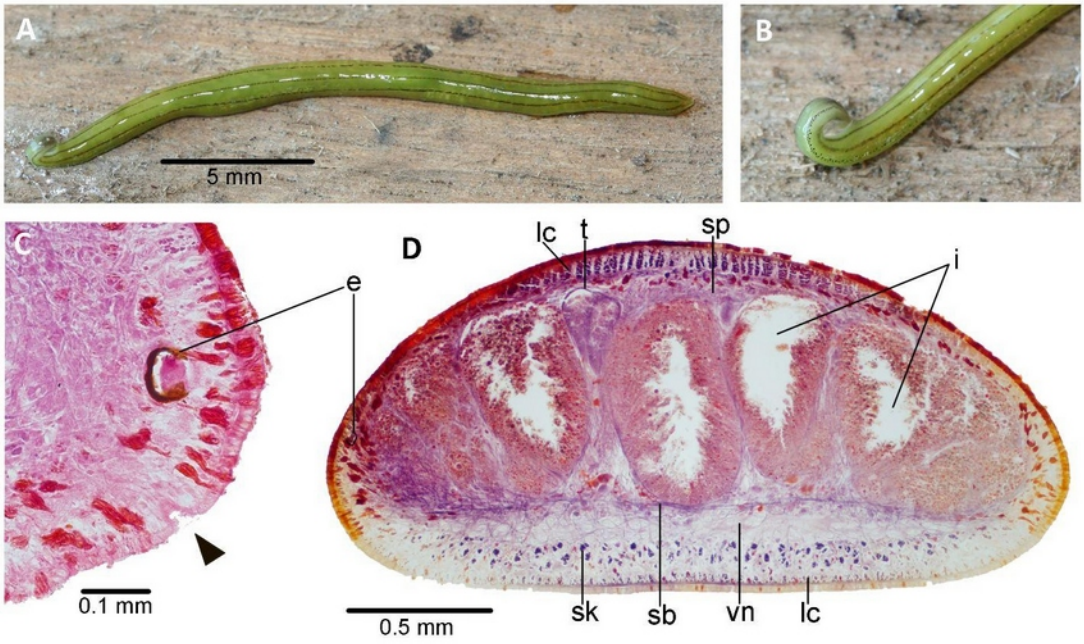


Fig. 2. Choeradoplana tristriata (Schultze and Müller, 1857), specimen F3226. **A** Dorsal view of the live specimen. **B** Lateral view of the anterior region of the live specimen. **C** Photomicrograph of a transverse section of the pre-pharyngeal region, showing an eye and a sensory pit (arrowhead). **D** Photomicrograph of a transverse section of the pre-pharyngeal region.

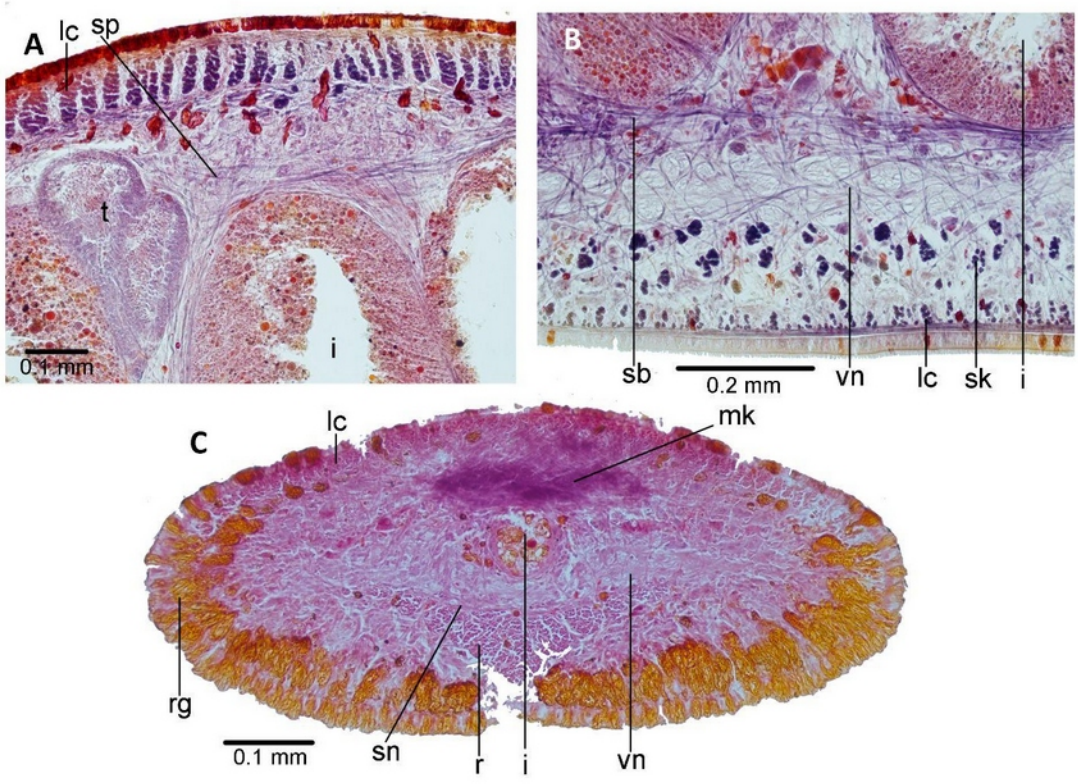


Fig. 3. Choeradoplana tristriata (Schultze and Müller, 1857), specimen F3226. Photomicrographs of transverse sections. **A** Dorsal portion of the pre-pharyngeal region. **B** Ventral region of the pre-pharyngeal region. **C** Cephalic region.

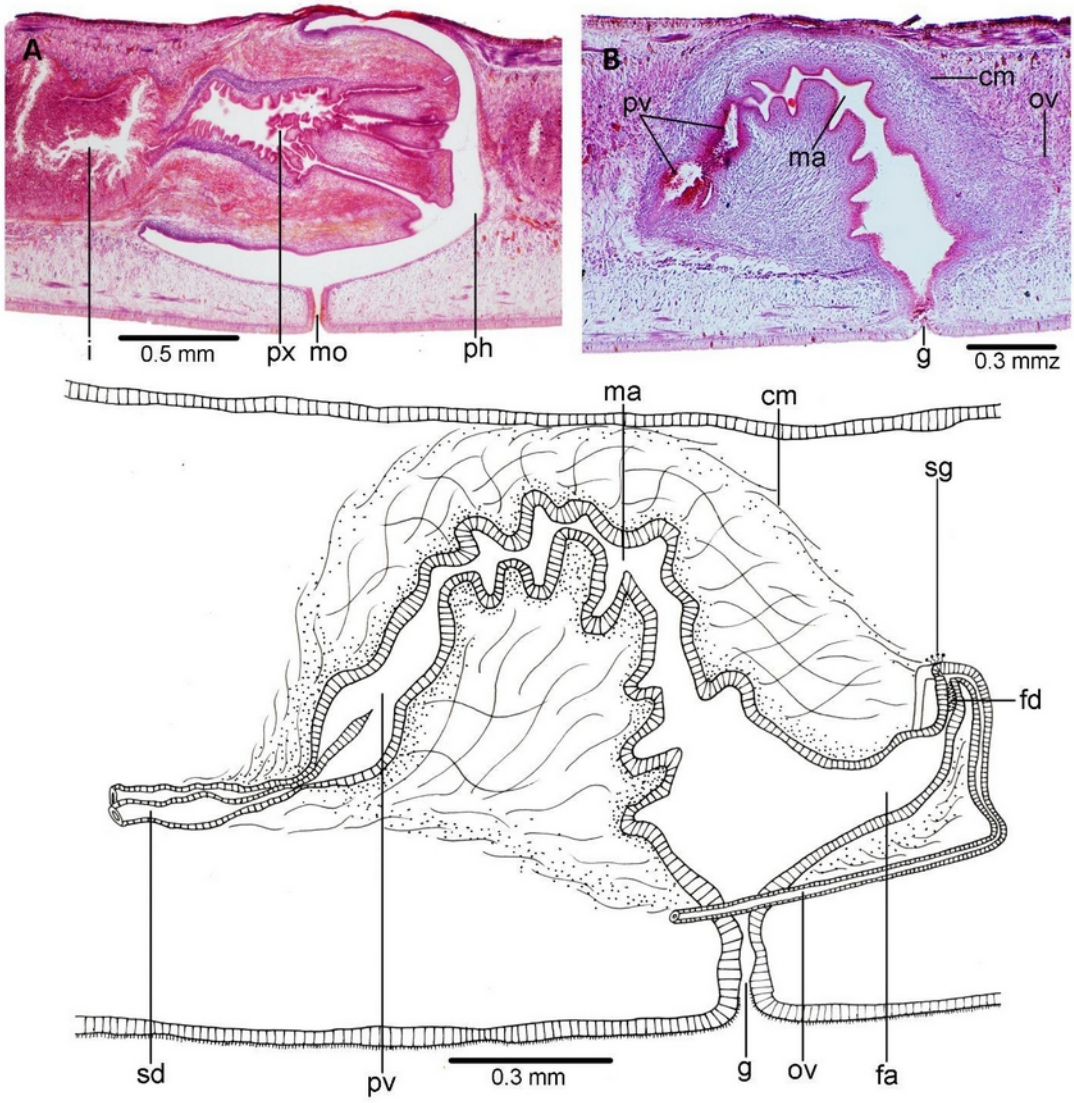


Fig. 4. Choeradoplana tristriata (Schultze and Müller, 1857), specimen F3226. **A** Photomicrograph of a sagittal section of the pharynx. **B** Photomicrograph of a sagittal section of the copulatory apparatus. **C** Diagrammatic representation of the copulatory apparatus.

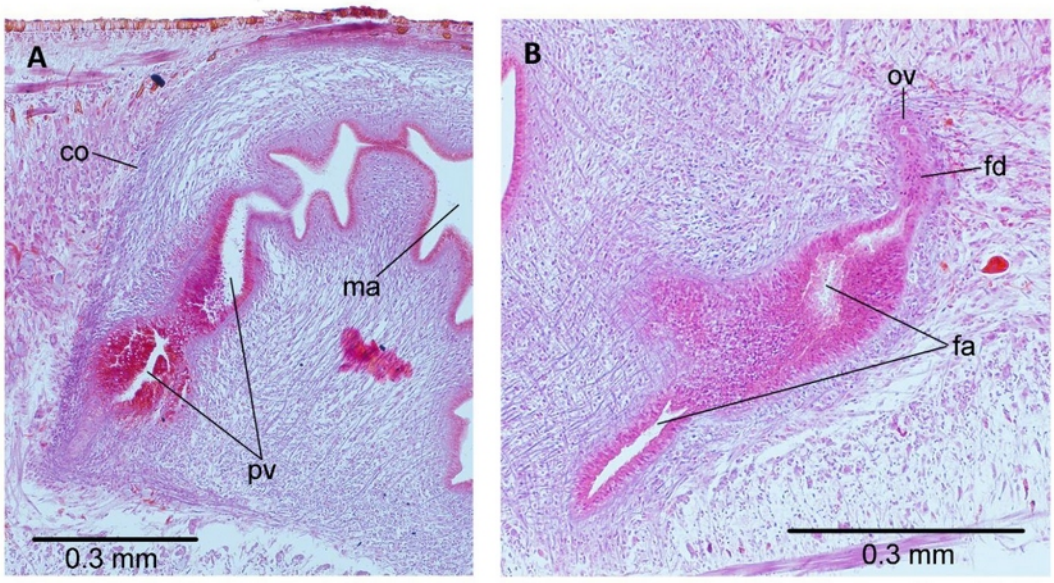


Fig. 5. Choeradoplana tristriata (Schultze and Müller, 1857), specimen F3226. Photomicrographs of sagittal sections. **A** Prostatic vesicle and the male atrium. **B** Female atrium.

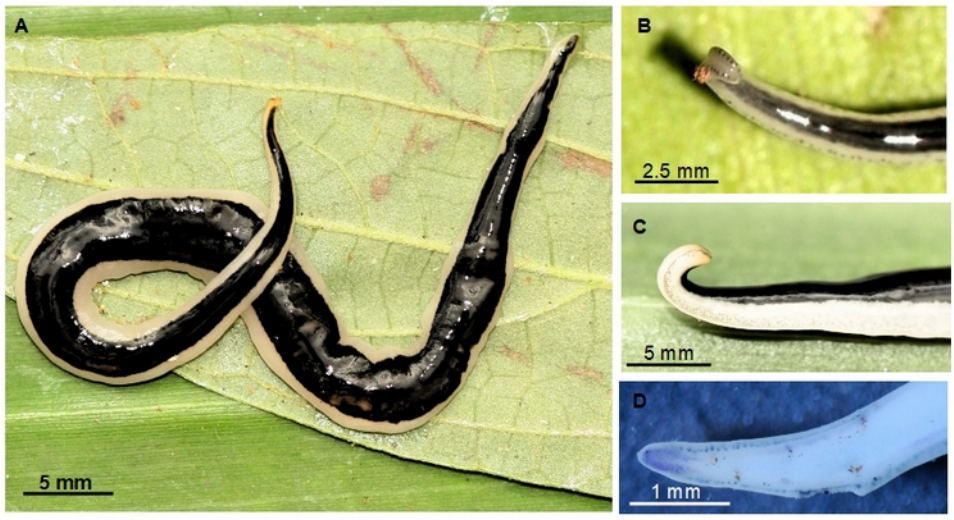


Fig. 6. Choeradoplana albonigra (Riester, 1938). **A** Habitus of living specimen F4024 in dorsal view. **B** Detail of anterior extremity of living specimen F2313 in dorsal view. Debris is glued on the body. **C** Detail of anterior extremity of living specimen F4024 in lateral view. **D** Detail of anterior extremity of preserved specimen F4031 in ventral view.

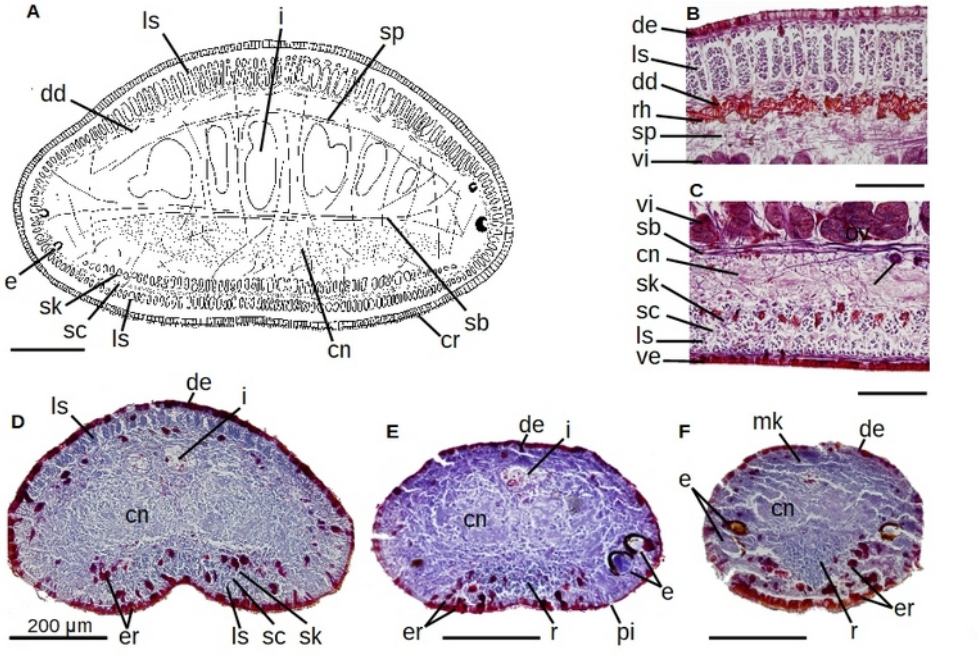


Fig. 7. Choeradoplana albonigra (Riester, 1938). **A** Diagrammatic transverse section of a portion, seemingly near the anterior extremity, of holotype. **B** Transverse section of the dorsal epidermis in pre-pharyngeal region of specimen F4024. **C** Transverse section of the ventral epidermis in pre-pharyngeal region of specimen F4024. **D-F** Three transverse sections of specimen F4081 at 1.2, 0.4, and 0.15 millimeters from anterior extremity of the body, respectively. Scale bar: 200 µm.

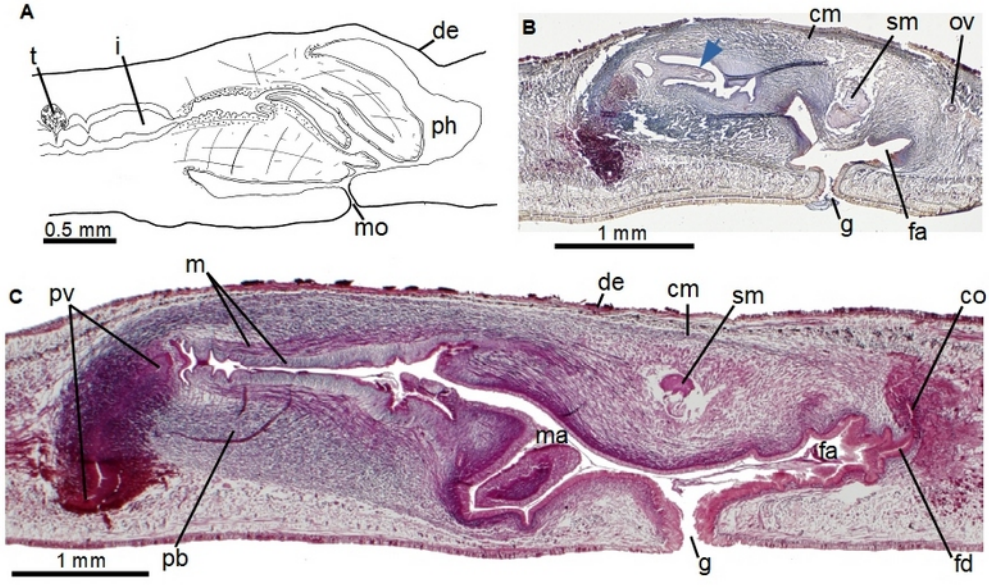


Fig. 8. Choeradoplana albonigra (Riester, 1938). **A** Diagrammatic representation of the pharynx from sagittal sections of holotype. **B** Sagittal section of the copulatory apparatus of specimen F2391. Note the small finger-shaped fold of the male atrium (arrowhead). **C** Photomicrograph of a sagittal section of the copulatory apparatus of specimen F4024.

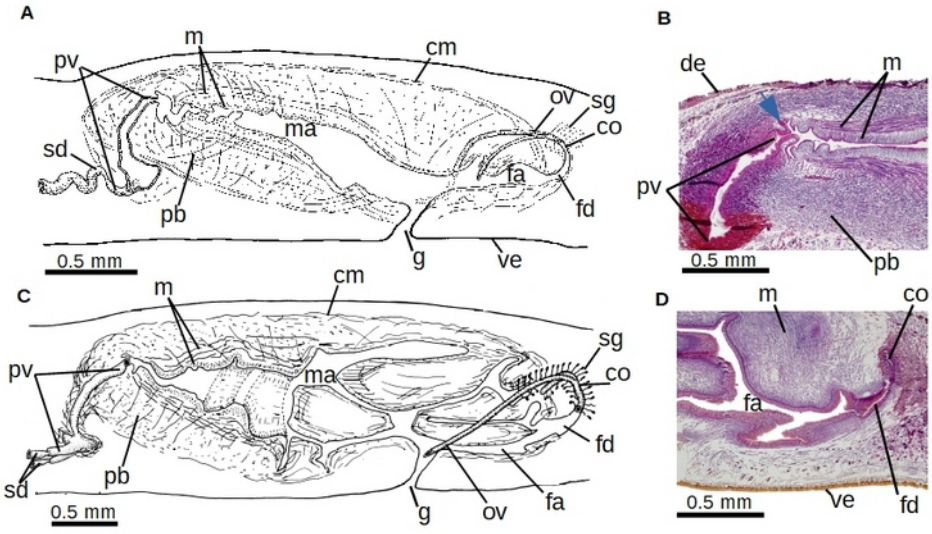


Fig. 9. Choeradoplana albonigra (Riester, 1938). **A** Diagrammatic reconstruction of copulatory apparatus of holotype from sagittal sections. **B** Photomicrograph of a sagittal section of the unpaired portion of the prostatic vesicle and proximal section of male atrium of specimen F4024 Arrowhead points the small ring-shaped horizontal fold communicating prostatic vesicle with male atrium. **C** Diagrammatic reconstruction of copulatory apparatus of specimen F4081 from sagittal sections. **D** Photomicrograph of a sagittal section of the female atrium of specimen F4081.

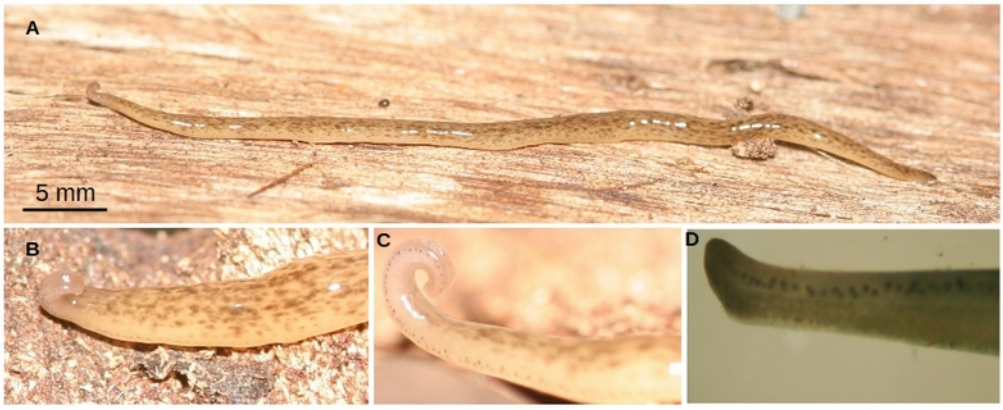


Fig. 10. Choeradoplana eudoxiae Silva and Carbayo, sp. nov. Holotype **A** Living holotype in dorsal view. **B-C** Detail of anterior extremity in a dorsal view. **D** Detail of anterior extremity preserved of holotype in ventro-lateral view.

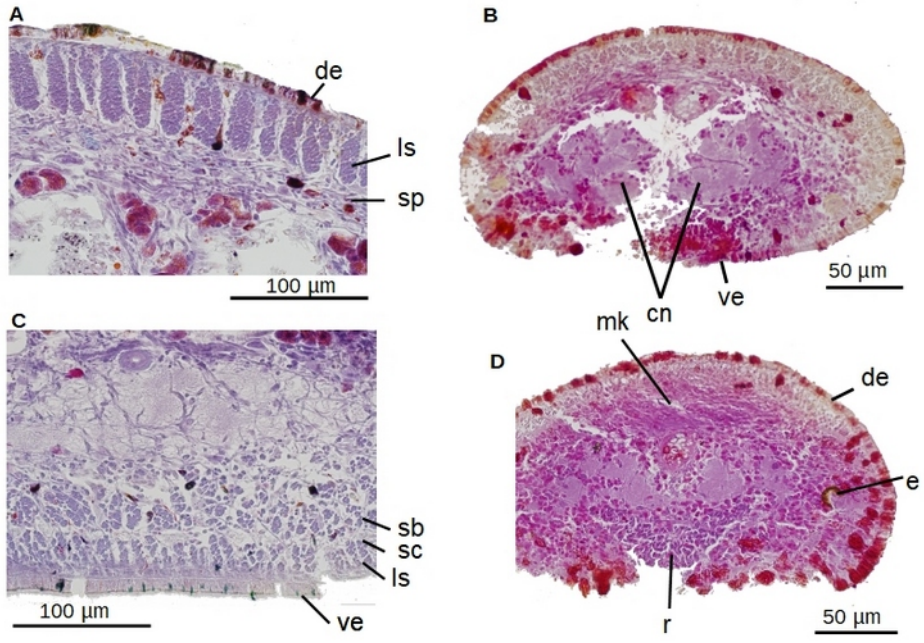


Fig. 11. Choeradoplana eudoxiae Silva and Carbayo, sp. nov. Photomicrographs of holotype. **A** Dorsal portion of a transverse section of anterior region. **B** Transverse section of anterior region. **C** Ventral portion of a transverse section of anterior region. **D** Transverse section anterior region.

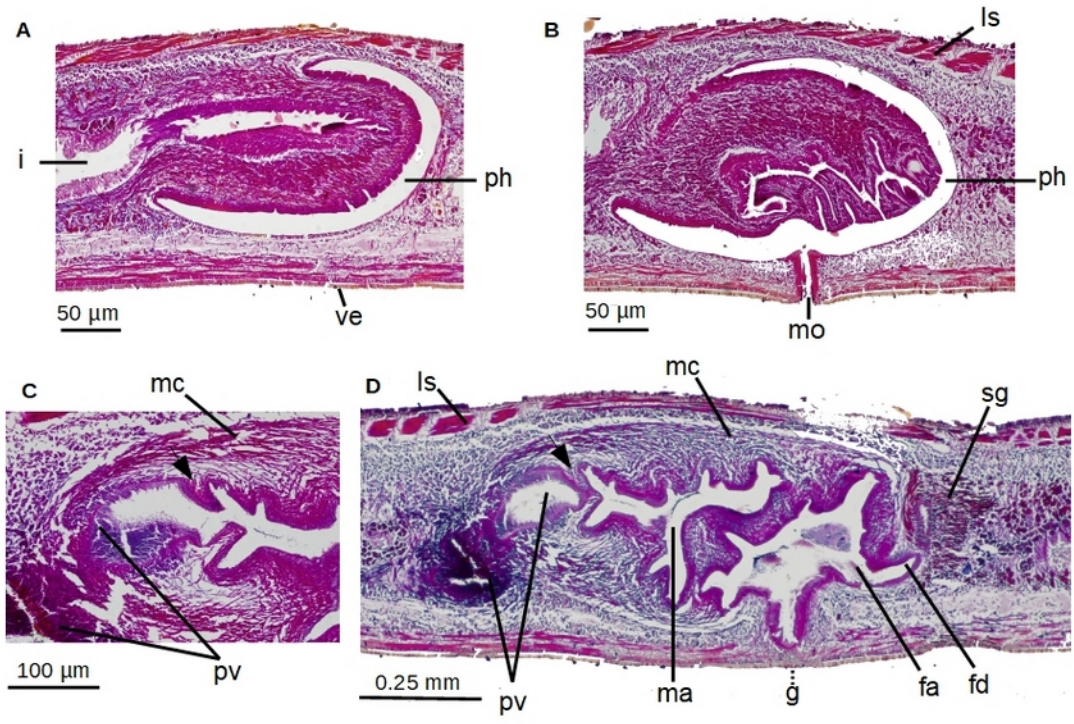


Fig. 12. Choeradoplana eudoxiae Silva and Carbayo, sp. nov. Photomicrographs of holotype. **A-B** Sagittal section of the proximal region of the pharynx. **C** Sagittal section of the prostatic vesicle and male atrium. **D** Sagittal section of copulatory apparatus.

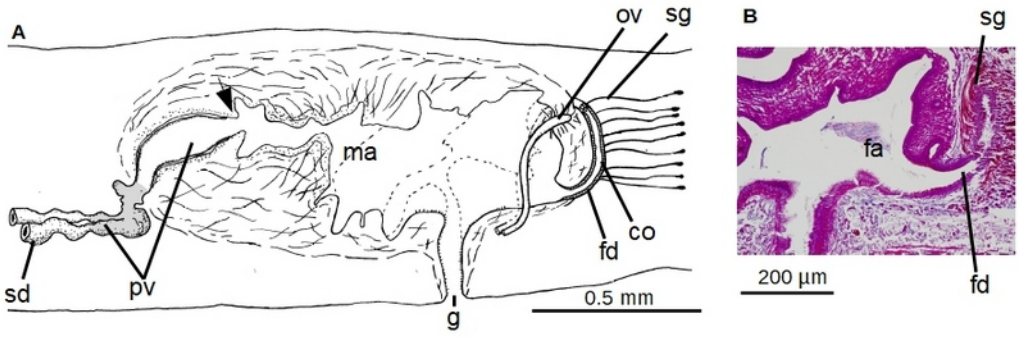


Fig. 13. Choeradoplana eudoxiae Silva and Carbayo, sp. nov. Holotype. **A** Diagrammatic reconstruction of copulatory apparatus. **B** Photomicrograph of a sagittal section of the female atrium.

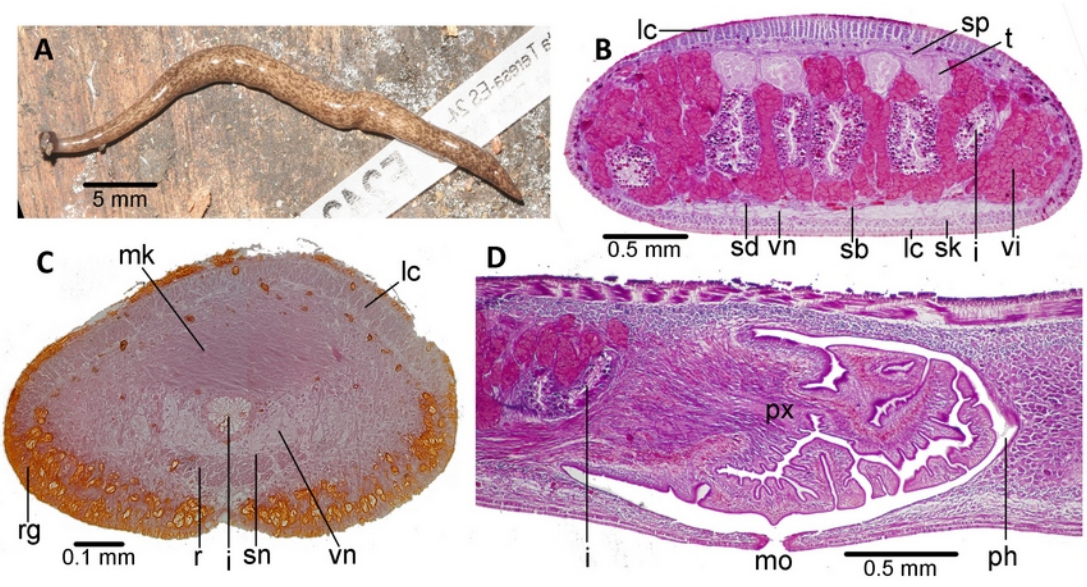


Fig. 14. Choeradoplana claudioi Lago-Barcia and Carbayo sp. nov., holotype F2424. **A** Dorsal view of the creeping live holotype. **B** Photomicrograph of a transverse section of the pre-pharyngeal region. **C** Photomicrograph of a transverse section of the cephalic region. **D** Photomicrograph of a sagittal section of the pharynx.

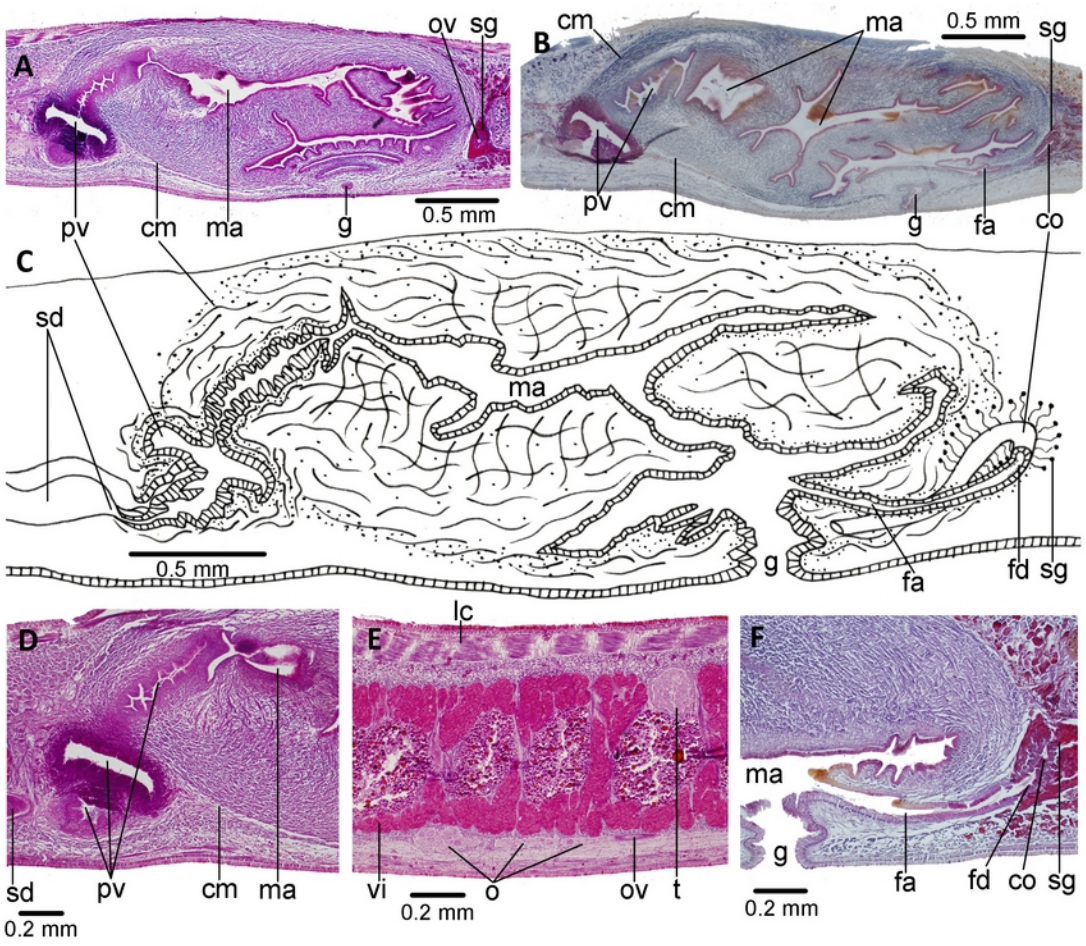


Fig. 15. Choeradoplana claudioi Lago-Barcia and Carbayo sp. nov. **A** Photomicrograph of a sagittal section of the copulatory apparatus of holotype F2424. **B** Photomicrograph of a sagittal section of the copulatory apparatus of paratype F2510. **C** Diagrammatic representation of the copulatory apparatus of holotype F2424. **D** Photomicrograph of a sagittal section of the prostatic vesicle of holotype F2424. **E** Photomicrograph of a sagittal section of the ovarian region of holotype F2424. **F** Photomicrograph of a sagittal section of the female atrium of holotype F2424.

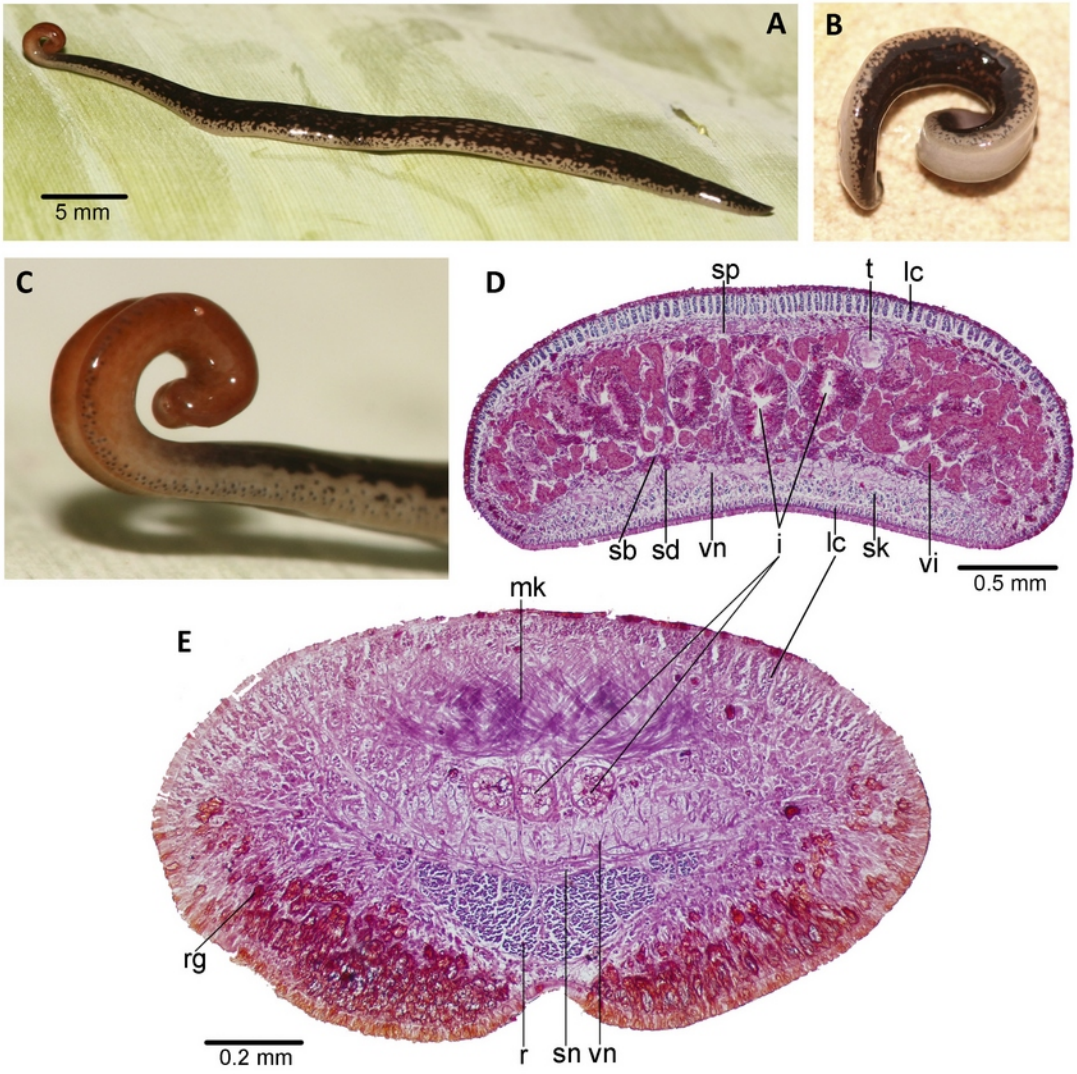


Fig. 16. Choeradoplana onae Lago-Barcia and Carbayo sp. nov. **A** Dorsal view of the creeping live paratype F2230. **B** Live paratype F2310 rolled up showing the ventral surface. **C** Lateral view of the cephalic region of paratype F2230. **D** Photomicrograph of a transverse section of the pre-pharyngeal region of holotype F2414. **E** Photomicrograph of a transverse section of the anterior region of holotype F2414.

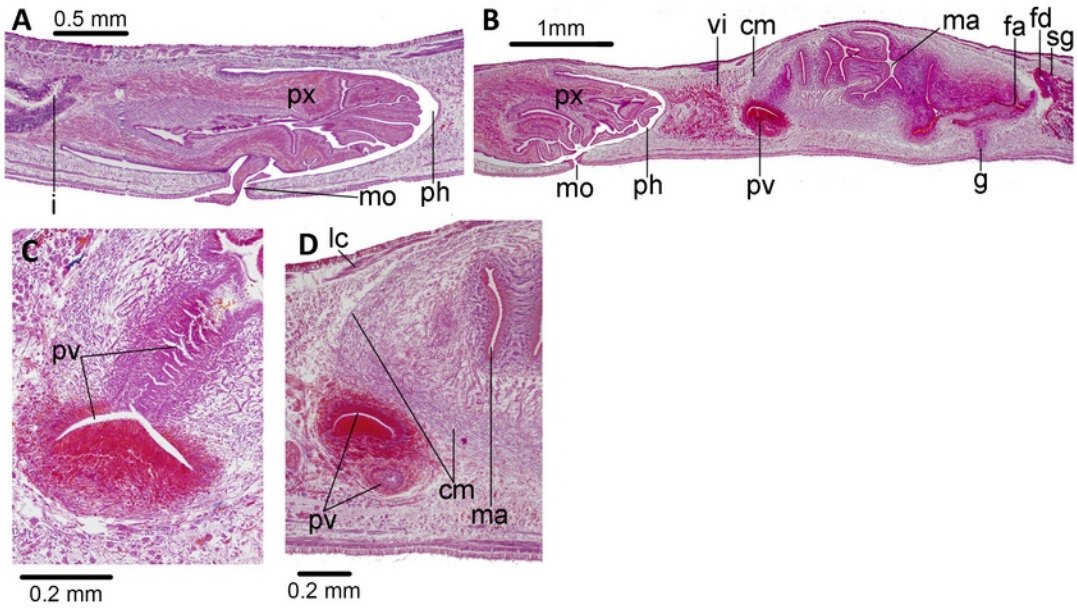


Fig. 17. Choeradoplana onae Lago-Barcia and Carbayo sp. nov. Photomicrographs of sagittal sections. **A** Pharynx of paratype F2230. **B** Pharynx and copulatory apparatus of holotype F2414. **C** Prostatic vesicle of paratype F2230. **D** Prostatic vesicle of holotype F2414.

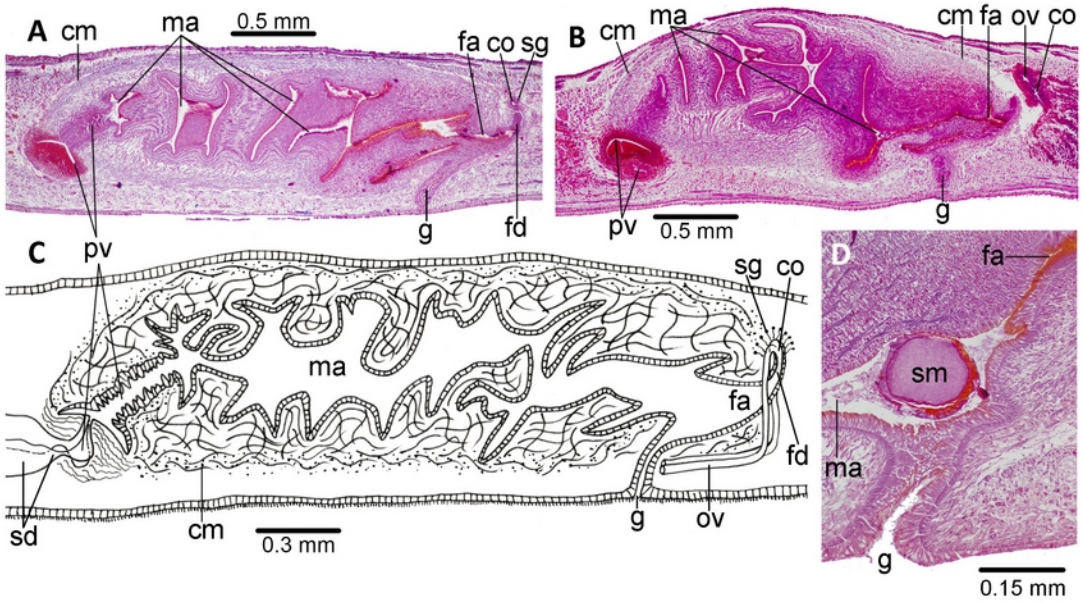


Fig. 18. Choeradoplana onae Lago-Barcia and Carbayo sp. nov. **A** Photomicrograph of a sagittal section of the copulatory apparatus of paratype F2230. **B** Photomicrograph of a sagittal section of the copulatory apparatus of holotype F2414. **C** Diagrammatic representation of the copulatory apparatus of paratype F2230. **D** Photomicrograph of a sagittal section of a spermatophore situated at the entrance of the gonopore of paratype F2281.

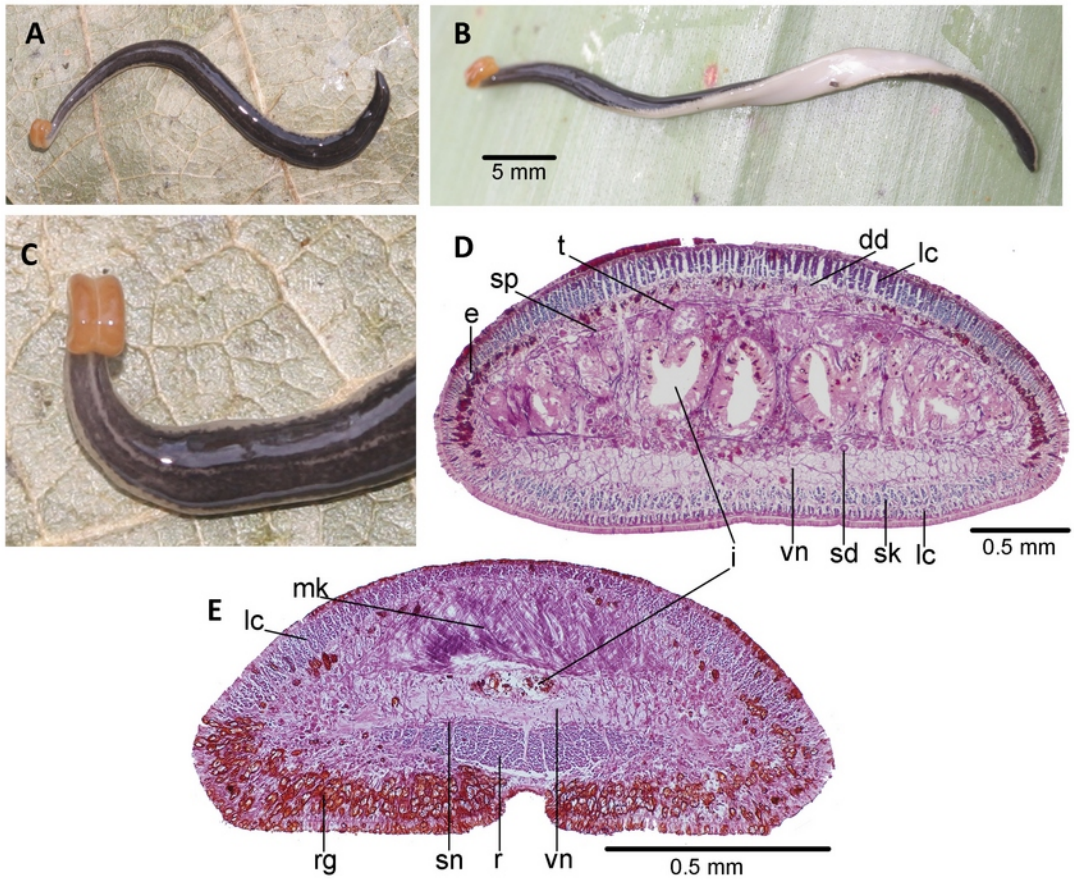


Fig. 19. Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov. **A** Dorsal view of the creeping live paratype F4217. **B** The live holotype F4218 twisted showing ventral surface. **C** Dorsal view of the anterior region of paratype F4217. **D** Photomicrograph of a transverse section of the pre-pharyngeal region of holotype F4218. **E** Photomicrograph of a transverse section of the cephalic region of holotype F4218.

Fig. 20. Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov., holotype F4218. Photomicrographs of sagittal sections. **A** Pharynx. **B** Prostatic vesicle.

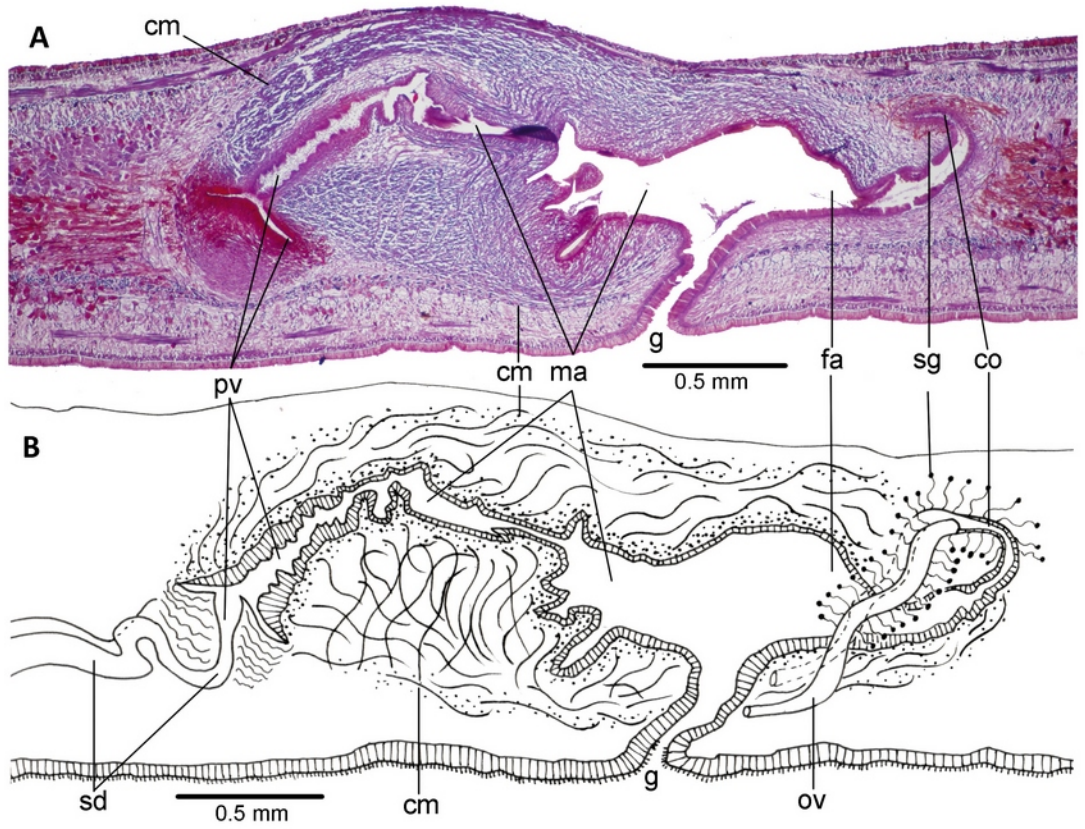


Fig. 21. Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov., holotype F4218. **A** Photomicrograph of a sagittal section of the copulatory apparatus. **B** Diagrammatic representation of the copulatory apparatus.

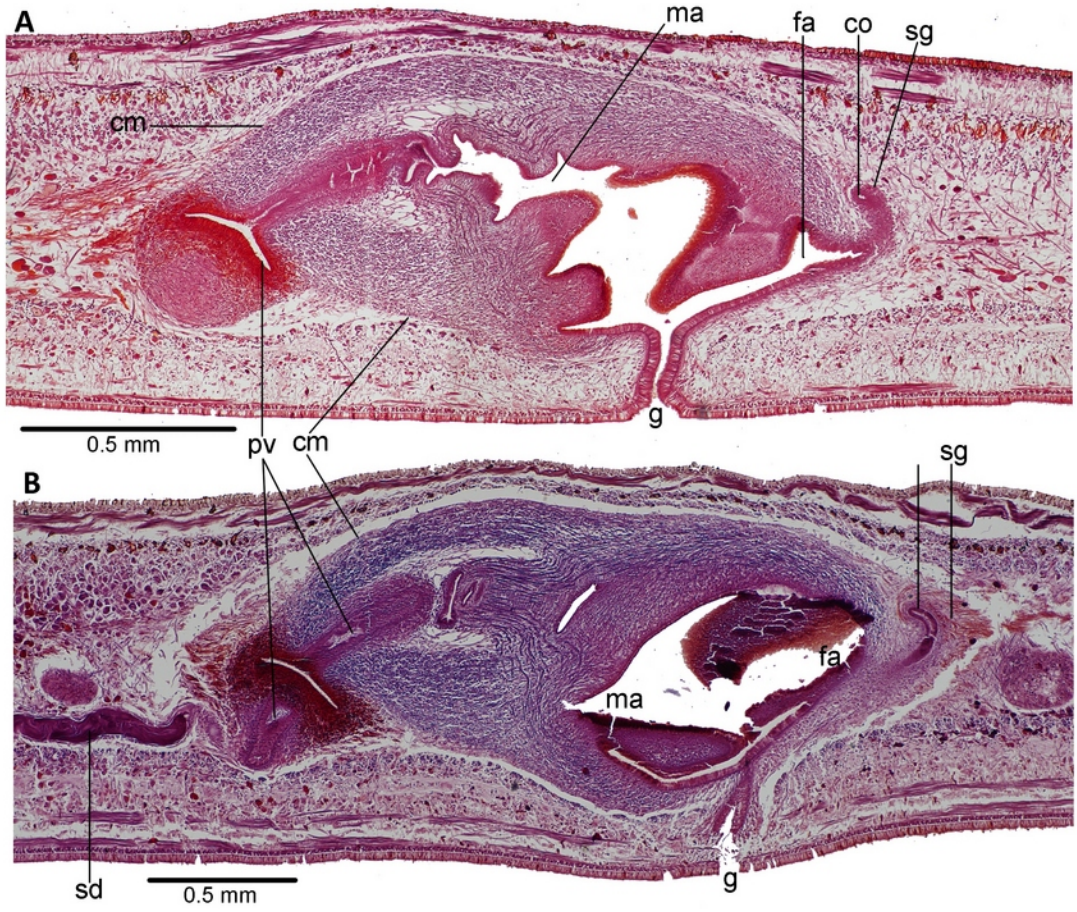


Fig. 22. Choeradoplana riutortae Lago-Barcia and Carbayo sp. nov. Photomicrographs of sagittal sections. **A** Copulatory apparatus of paratype F4217. **B** Copulatory apparatus of paratype F4261.

Tables

Tab. 1. List of samples used in this study showing species name, field number, museum accession number, type specimen status, collection locality and date, and GenBank accession number.

Species	Field Number	Accession Number	Type specimen	Coll. locality in Brazil	Coll. Date	GenBank Acc. N.º (COI)
Choeradoplana abaiba Carbayo *et al.,* 2018	F3905	MZUSP PL 1170	-	Parque Estadual da Serra do Tabuleiro, SC	07/14/09	MF802634
Choeradoplana abaiba Carbayo *et al.,* 2018	F3894	MZUSP PL 1169	-	Parque Estadual da Serra do Tabuleiro, SC	07/13/09	MF802633
Choeradoplana abaiba Carbayo *et al.,* 2018	F3865	MZUSP PL 1167	-	Parque Estadual da Serra do Tabuleiro, SC	07/12/09	MF802631
Choeradoplana abaiba Carbayo *et al.,* 2018	F3866	MZUSP PL 1168	-	Parque Estadual da Serra do Tabuleiro, SC	07/12/09	MF802632
Choeradoplana abaiba Carbayo *et al.,* 2018	F3864	MZUSP PL 1166	Holotype	Parque Estadual da Serra do Tabuleiro, SC	07/12/09	MF802630
Choeradoplana abaiba Carbayo *et al.,* 2018	F3312	MZUSP PL 509	Paratype	Parque Estadual da Serra do Tabuleiro, SC	01/17/09	MF802629
Choeradoplana abaiba Carbayo *et al.,* 2018	F3270	MZUSP PL 505	-	Parque Estadual da Serra do Tabuleiro, SC	01/15/09	MF802628
Choeradoplana abaiba Carbayo *et al.,* 2018	F3315	MZUSP PL 511	-	Parque Estadual da Serra do Tabuleiro, SC	01/17/09	HQ542891
Choeradoplana agua Carbayo et al., 2018	F2214	MZUSP PL 448	-	Parque Estadual do Desengano, RJ	03/19/08	MF802637
Choeradoplana agua Carbayo et al., 2018 *	F2205	MZUSP PL 446	Paratype	Parque Estadual do Desengano, RJ	03/18/08	MF802636
Choeradoplana agua Carbayo et al., 2018	F2204	MZUSP PL 445	Paratype	Parque Estadual do Desengano, RJ	03/18/08	MF802635
Choeradoplana agua Carbayo et al., 2018 *	F2205	MZUSP PL 446	Paratype	Parque Estadual do Desengano, RJ	03/18/08	KF971686
Choeradoplana agua Carbayo et al., 2018	F3952	MZUSP PL 619	Paratype	Parque Estadual do Desengano, RJ	08/09/08	KF971680
Choeradoplana albonigra (Riester, 1938)	SMF Nº702	-	Holotype	Teresópolis, RJ	04/09/14	-
Choeradoplana albonigra (Riester, 1938)	F2313	MZUSP PL 1109	-	Reserva Biológica Augusto Ruschi, ES	26/05/08	KF971684
Choeradoplana albonigra (Riester, 1938)	F2391	MZUSP PL 1113	-	Reserva Biológica Augusto Ruschi, ES	27/05/08	KF971683
Choeradoplana albonigra (Riester, 1938)	F3991	MZUSP PL 2273	-	Parque Estadual do Desengano, RJ	08/10/09	-
Choeradoplana albonigra (Riester, 1938)	F4024	MZUSP PL 2152	-	Parque Estadual do Desengano, RJ	08/11/09	-
Choeradoplana albonigra (Riester, 1938)	F4031	MZUSP PL 2153	-	Parque Estadual do Desengano, RJ	08/11/09	-

Choeradoplana albonigra (Riester, 1938)	F4081	MZUSP PL 1083	-	Parque Estadual do Desengano, RJ	08/13/09	KC608327
Choeradoplana banga Carbayo & Froehlich, 2012	F3706	MZUSP PL 568	-	Parque Estadual da Cantareira, SP	04/19/09	MF802639
Choeradoplana banga Carbayo & Froehlich, 2012	F3006	MZUSP PL 1001	Paratype	Parque Estadual da Cantareira, SP	12/14/08	MF802638
Choeradoplana banga Carbayo & Froehlich, 2012	F2023	MZUSP PL 1000	Holotype	Parque Estadual da Cantareira, SP	01/30/08	KC608267
Choeradoplana banga Carbayo & Froehlich, 2012	F3011	MZUSP PL 1002	Paratype	Parque Estadual da Cantareira, SP	12/14/08	KC608301
Choeradoplana benyai Lemos & Leal-Zanchet, 2014	F3813	MZUSP PL 1165	-	Parque Estadual da Serra do Tabuleiro, SC	07/12/09	MF802641
Choeradoplana benyai Lemos & Leal-Zanchet, 2014	F3494	MZUSP PL 1163	-	Floresta Nacional de São Francisco de Paula, RS	01/28/09	MF802640
Choeradoplana benyai Lemos & Leal-Zanchet, 2014	-	MZU PL.00151	Paratype	Floresta Nacional de São Francisco de Paula, RS	03/21/10	KJ690049
Choeradoplana sp.	F2332	MZUSP PL 2276	-	Reserva Biológica Augusto Ruschi, ES	26/05/08	MW127841*
Choeradoplana sp.	F2390	MZUSP PL 1155	-	Reserva Biológica Augusto Ruschi, ES	27/05/08	MW127842*
Choeradoplana bocaina Carbayo & Froehlich, 2012	F2822	MZUSP PL 997	Holotype	Parque Nacional da Serra da Bocaina, SP	09/08/09	KC608288
Choeradoplana bocaina Carbayo & Froehlich, 2012	F2104	MZUSP PL 999	Paratype	Parque Nacional da Serra da Bocaina, SP	02/10/08	KC608273
Choeradoplana bocaina Carbayo & Froehlich, 2012	F2803	MZUSP PL 998	Paratype	Parque Nacional da Serra da Bocaina, SP	09/07/08	KC608283
Choeradoplana claudioi sp. nov.	F2424	MZUSP PL 1156	Holotype	Reserva Biológica Augusto Ruschi, ES	28/05/08	MW127839*
Choeradoplana claudioi sp. nov.	F2510	MZUSP PL 1157	Paratype	Reserva Biológica Augusto Ruschi, ES	29/05/08	MW127840*
Choeradoplana eudoxiae Silva & Carbayo, sp. nov.	F3417	MZUSP PL 2272	Holotype	Floresta Nacional de São Francisco de Paula, RS	01/22/09	-
Choeradoplana gladismarie Carbayo *et al.* 2013	F3802	MZUSP PL 1004	Paratype	Parque Estadual Intervales, SP	07/07/09	KC608326
Choeradoplana gladismarie Carbayo *et al.* 2013	F3092	MZUSP PL 1003	Holotype	Parque Estadual Intervales, SP	12/12/08	KC608306
Choeradoplana iheringi Graff, 1899	F3465	MZUSP PL 537	-	Floresta Nacional de São Francisco de Paula, RS	01/25/09	MF802660
Choeradoplana iheringi Graff, 1899	F3454	MZUSP PL 535	-	Floresta Nacional de São Francisco de Paula, RS	01/25/09	MF802658
Choeradoplana iheringi Graff, 1899	F3447	MZUSP PL 531	-	Floresta Nacional de São Francisco de Paula, RS	01/25/09	MF802654
Choeradoplana iheringi Graff, 1899	F3430	MZUSP PL 528	-	Floresta Nacional de São Francisco de Paula, RS	01/23/09	MF802651

Choeradoplana iheringi Graff, 1899	F3409	MZUSP PL 524	-	Floresta Nacional de São Francisco de Paula, RS	01/22/09	MF802649
Choeradoplana iheringi Graff, 1899	-	MZU PL.00156	-	?		KJ690046
Choeradoplana marthae Froehlich, 1955	F2137	MZUSP PL 1153	-	Estação Biológica de Boraceia, SP	02/14/08	MF802665
Choeradoplana minima Lemos & Leal-Zanchet, 2014	-	MZU PL.00143	Paratype	Floresta Nacional de São Francisco de Paula, RS	02/25/10	KJ690052
Choeradoplana minima Lemos & Leal-Zanchet, 2014	-	MZU PL.00145	Paratype	Floresta Nacional de São Francisco de Paula, RS	06/09/11	KJ690051
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2230	MZUSP PL 2267	Paratype	Reserva Biologica de Ruschi, SP	05/24/08	MW127834*
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2235	MZUSP PL 2277	-	Reserva Biologica de Ruschi, SP	05/24/08	MW127837*
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2281	MZUSP PL 2268	Paratype	Reserva Biologica de Ruschi, SP	26/05/08	MW127836*
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2310	MZUSP PL 2269	Paratype	Reserva Biologica de Ruschi, SP	26/05/08	MW127838*
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2414	MZUSP PL 2270	Holotype	Reserva Biologica de Ruschi, SP	27/05/08	MW127835*
Choeradoplana onae Lago-Barcia & Carbayo, sp. nov.	F2311	MZUSP PL 1108	-	Reserva Biologica de Ruschi, SP	26/05/08	KF971685
Choeradoplana pucupucu Carbayo *et al.,* 2018	F2844	MZUSP PL 541	Holotype	Parque Nacional da Serra da Bocaina, SP	09/01/08	MF802666
Choeradoplana pucupucu Carbayo *et al.,* 2018	F2840	MZUSP PL 540	Paratype	Parque Nacional da Serra da Bocaina, SP	09/20/08	KC608293
Choeradoplana riutortae Lago-Barcia & Carbayo, sp. nov.	F4217	MZUSP PL 1174	Paratype	Parque Nacional da Serra dos Orgãos, RJ	01/06/10	MW148795 *
Choeradoplana riutortae Lago-Barcia & Carbayo, sp. nov.	F4218	MZUSP PL 2274	Holotype	Parque Nacional da Serra dos Orgãos, RJ	01/06/10	-
Choeradoplana riutortae Lago-Barcia & Carbayo, sp. nov.	F4261	MZUSP PL 2275	Paratype	Parque Nacional da Serra dos Orgãos, RJ	01/08/10	-
Choeradoplana tristriata (Schultze & Müller, 1857)	F3226	MZUSP PL 2271	-	Parque Estadual da Serra do Tabuleiro, SC	01/11/09	MW127833*
Matuxia matuta (Froehlich, 1955)	F2184	MZUSP PL 1021	-	Parque Estadual do Desengano, RJ	03/17/08	KC608276
Matuxia matuta (Froehlich, 1955)	F2187	MZUSP PL 1022	-	Parque Estadual do Desengano, RJ	03/17/08	KC608277
Choeradoplana sp. (in Álvarez-Presas *et al.,* 2014)	F4063	MZUSP PL 636	-	Parque Estadual do Desengano, RJ	08/12/09	KF971679

Chapter 3

Phylogenetic relationships of the Geoplaninae land planarians (Platyhelminthes, Tricladida) assessed with a total evidence approach

This manuscript has not yet been submitted for publication. Lago-Barcia D, Álvarez-Presas M, Riutort M, Oceguera-Figueroa A, Carbayo F. Phylogenetic relationships of the Geoplaninae land planarians (Platyhelminthes, Tricladida) assessed with a total evidence approach. Ready for submission.

Abstract

The intergeneric and deeper phylogenetic relationships of the Geoplaninae land planarians still remain obscure. In this study, we assess the elusive internal relationships of the Geoplaninae in a total evidence approach (TE). Our data matrix consisted of six DNA regions, including newly developed markers, and a morphological matrix with 37 characters. The TE produced the best-resolved hypothesis so far for the phylogeny of Geoplaninae. The largest clades in the TE tree as well as the relationships within each deeper clade are overall congruent with previous studies, but more robust. Although some clades lack high statistical support, our phylogenetic inference suggests that most of the morphological characters traditionally used in the diagnoses of the genera are homoplastic or plesiomorphic. These observations strengthen convergence and regression as recurrent processes along the evolution of the Geoplaninae.

Introduction

In the last years, some effort has been addressed to understand the phylogenetic interrelationships of the Geoplanidae (Tricladida, Platyhelminthes), the family

comprising the land planarians. Currently the group is divided into five subfamilies from which the internal phylogenetic relationships of the Geoplaninae, have probably received more attention. Endemic to the Neotropical region, Geoplaninae comprises over 346 species (planarias.each.usp.br; accessed in July 2021) grouped in 29 genera. Early classifications and phylogenetic studies of the land planarians were based on ecological and morphological attributes (Hallez, 1892, 1893, 1894; Graff, 1896, 1899; Pantin, 1953). These types of studies were valuable, but they lacked reproducible methodological approaches (e.g., Graff, 1899; Meixner, 1928; Marcus, 1953; Froehlich, 1967; Winsor et al., 1998). In two unpublished theses, Winsor (2003) and Carbayo (2003) mapped and evaluated external and internal morphological characters aimed at a future cladistic approach of the Geoplanidae and Geoplaninae, respectively. In two other unpublished theses, Grau (2010) and Amaral (2017) explored the same and additional characters to investigate the internal relationships of Geoplaninae. Both recovered the monophyly of the Geoplaninae (Grau, 2010; Amaral, 2017), although the internal relationships did not match each other.

Early studies using the Platyhelminthes as the main focus group, indicated molecular evidence of the monophyly of the family Geoplanidae (Carranza et al., 1997). A molecular study of the order Tricladida, showed the monophyly of the Geoplaninae (Álvarez-Presas et al., 2008) although the representativeness of Geoplaninae was poor. Later on, the classification of the group was widely impacted by a molecular phylogeny carried out by Carbayo et al. (2013). It was seen that most genera inside the Geoplaninae are seemingly monophyletic. Nonetheless, intergeneric and deeper phyletic relationships of the subfamily still remained obscure.

An unexplored field of phylogenetic inference of land planarians is the total evidence approach. Phylogenetic hypotheses are best determined if based on multiple lines of evidence (e. g., Nixon & Carpenter, 1996; Littlewood et al., 1998; Jenner, 2004, Kluge, 2004, 2009; Cabra-García & Horminga, 2020). The aim of a total evidence

analysis (TE) is to use character congruence to achieve the best-fitting phylogenetic hypothesis, using all of the available character evidence (Eernisse and Kluge, 1993). Usually, these character evidence are morphology and molecular (DNA) data. Although there is some excepticism to the actual weight of morphological data among an overwhelming amount of nucleotide data (Lee & Palci, 2015), a TE approach has also revealed robust phylogenetic interrelationships in reluctant taxonomic groups (e.g., Murrell et al., 2001; Morales et al., 2020; Du et al., 2021).

In this study, we combined morphological and molecular data in a total evidence approach and incorporated previous and newly developed molecular markers together with 37 morphological characters, in order to clarify the older relationships between the Geoplaninae genera.

Materials and methods

Specimen collection and preparation

Seventy-four specimens representing 48 taxa were included in this study plus three species used as outgroups (Tab. 1). The individuals were collected by the authors between 2004 and 2016 from conservation areas located in the southern region of the Atlantic Forest, between the States of Bahia and Rio Grande do Sul, in Brazil. From each specimen a small portion was destined for molecular studies and preserved in absolute ethanol. The remaining body was destined for morphological studies, fixed in 10% formalin or 95% ethanol and preserved in 80% ethanol. Specimen collection and histological glass slides preparations followed Lago-Barcia et al. (2021).

Matrix for morphological characters

The morphological dataset represents the morphological variation among species and genera within Geoplaninae showing to be taxonomically relevant. The 37

morphological characters include external and internal attributes of each species. These characters do not present intraspecific variation. Character states were coded from observations of specimens (naked eye and stereomicroscope for external attributes; and light microscope for internal attributes) and from the literature (see Supp. Tab. 1 for specimens examined). These characters refer to the body shape and eyes (8 characters), sensory pits (3), gland cells (2), cutaneous and parenchymatic muscle organization (9), and anatomical details of the pharynx (3), and copulatory apparatus (12). Characters or their states which were not available in the literature or for examination were considered as missing data and codified as "?".

The external morphological characters sum up general body morphological traits, details from the anterior extremity of the body and details on eyes; the sensory pit characters are often difficult to observe as sensory pits are small structures (~10-30 μm deep); muscle characters depend on number, position, shape, thickness and orientation of the muscle layers in different muscle systems; the copulatory apparatus (category with highest number of characters) is the most informative region of the body when looking for diagnostic characters, and information can be obtained from the different copulatory organs such as the prostatic vesicle, the penis papilla, the ovaries or testicles, the male and female atria, for example.

Morphological phylogenetics

The morphological phylogenetic inference was carried out using the morphological dataset (Supp. Tab. 1) which included just one terminal for each species, i. e., 46 taxa included. Unknown state characters were considered as missing ("?"). The species belonging to the family Rhynchodemidae, *Endeavouria septemlineata* (Hyman, 1939) and *Anzoplana tristriata* (Winsor, 2006) were used as an outgroup. The analyses were performed with Maximum Likelihood (ML) inference in the software IQtree2 v2.1.2 (Nguyen et al., 2015) using the evolutionary model MK+ASC, and setting

parameters to 10,000 replicates of UltraFast Bootstrap to measure support values; and with Bayesian Inference (BI) in the software RevBayes (Höhna et al., 2016) using the MK model and 200,000 iterations split in two separate runs. The morphological matrix is available as Supp. Mat. 1.

Nomenclature of species, clades and terminals

Some species included in this study are considered *incertae sedis* in a previous molecular phylogeny (see Carbayo et al., 2013) since they are placed in different clades from that including the type species of the genus. Therefore, the genus is non-monophyletic. In the present paper, species out of the clade including the type species are mentioned with the genus name in quotation marks, such as *"Geoplana" quagga* Marcus, 1951.

Species not formally described are mentioned as sp. An undescribed species not assignable to any of the current genera is referred to as Geoplaninae followed by an integer. Clades in the inferred phylogenies were informally named with alphabetical capital letters for the purpose of facilitating description and comparison among trees.

To distinguish terminals of species represented by two or more individuals an integer was added to the species name.

DNA extraction, amplification and sequencing

Whenever possible, two specimens of every species were selected for the molecular analyses. Genomic DNA was extracted using the Wizard® Genomic DNA Purification Kit (Promega, Madison, WI, USA). Six DNA regions were amplified: the mitochondrial cytochrome oxidase I gene (COI, ~900 pb), and five nuclear regions: three of them corresponding to the genes in the ribosomal cluster 18S rDNA type II (18S, ~1600 pb) and 28S rDNA (28S, ~1700 pb), the gene encoding for the elongation factor 1-alpha gene (EF, ~650 pb), a molecular marker corresponding to the Rho2-

GTPase region (named Tnuc813 following Araujo et al., 2020) and a new nuclear marker named DOM5 tested for the first time here. The design of DOM5 primers was done using scaffolded reads from a low coverage genome sequencing using the software DOMINO (Development Of Molecular Markers In Non-model Organisms) (Frías-López et al., 2016) to automate the search for variable regions located between conserved areas without limiting the search to intronic regions. The DNA fragment amplified by the DOM5 primers, turned out to correspond to the sequence of the heat shock protein 70 (hsp70) and not to be an anonymous marker. Primers used for the present study and PCR annealing temperatures are presented in Tab. 2. Standard PCR reactions were performed using Go Taq® DNA polymerase (Promega) in a total volume of 25 µl, which included 0.5 ml of each primer (10 mM) and 2 ml of template DNA. Amplification products were purified using a vacuum manifold (Multiscreen®HTS Vacuum Manifold, Millipore Corporation, Billerica, MA 01821, USA) before Sanger sequencing in Macrogen Europe. The same primers were used for PCR amplification and sequencing. The chromatograms were checked for quality and the contigs obtained with Geneious 10.2.6 (Biomatters, http://www.geneious.com).

Molecular phylogenetic inference

Newly obtained sequences were aligned with sequences from the GenBank database, building six molecular datasets named as follows: 18S, 28S, COI, EF, DOM5, and Tnuc813. A *Concatenated* dataset was also built by concatenating the six genes. Species of the subfamily Geoplaninae are the ingroup, whereas two species from the subfamily Rhynchodeminae (*Dolichoplana striata* Moseley, 1877 and *Endeavouria septemlineata*) were used as outgroup. For the Tnuc813 and DOM5 single-gene phylogenies, freshwater planarians were used as outgroups since sequences of Rhynchodeminae were not available.

Datasets with ribosomal gene sequences 18S and 28S were aligned using the online version of the software MAFFT v7 (Katoh & Standley, 2013), using the G-INS-i method and the default settings. The alignments were then processed with Gblocks 0.91b (Talavera & Castresana, 2007) to get rid of poorly aligned positions, allowing 30 as a maximum number of contiguous non-conserved positions and setting the minimum length of a block to 4. Gaps were allowed in up to half of the taxa. Datasets with encoding genes (COI, EF, Tnuc813 and DOM5) were aligned based on the amino acid translation as guide, using the mitochondrial genome of Echinoderms and Platyhelminthes (codon table number 9) for the COI dataset, and the universal codon table for the other datasets (EF, Tnuc813 and DOM5). Introns present in the Tnuc813 dataset were aligned independently using MAFFT. Alignments were revised manually in BioEdit v7.2.5 (Hall, 1999) to check for possible errors. A saturation test was carried out using the software DAMBE (Xia, 2018) to see the saturation levels of the third position of the gene COI, which has shown levels of saturation throughout other studies, including Tricladida (Álvarez-Presas et al., 2008).

The individual gene alignments were analysed under the Maximum Likelihood (ML) inference using the software IQtree2 v2.1.2 (Nguyen et al., 2015) with 10,000 ultrafast bootstrap (UFB) replicates and estimating the model with ModelFinder (MFP+MERGE option). The *Concatenated* dataset was analysed using both ML and BI approaches. The best fitting substitution models and data partitioning scheme were selected using PartitionFinder2 v2.1.1. (Lanfear et al., 2017) as implemented on the CIPRES Science Gateway (Miller et al., 2010), dividing the dataset by gene with unlinked branch lengths and following the AICc criteria for selecting the best fit model. The ML inference was run in IQtree2 v2.1.2 (Nguyen et al., 2015) using the partition scheme resulting from the PartitionFinder (PF) analysis. BI analysis was performed with the software RevBayes (Höhna et al., 2016) using the same PF partition scheme and the model GTR+G for each partition independently. After 5,000,000 iterations convergence

was assessed using the software Tracer v.1.7 (Rambaut & Drummond, 2007) and a majority consensus tree was obtained with a standard burning of 10%.

Total Evidence Phylogenetic Analysis

To perform a phylogenetic analysis of combined data (morphological and molecular data), we used the concatenated dataset with the molecular sequences of 74 terminals (5414 bp) and the morphological matrix with 37 variable characters. The dataset was analysed using ML inference in IQtree2 v2.1.2. The Mk+ASC model was applied to the morphological characters for correcting the likelihood conditioned on variable sites and the PF parameters were applied to the molecular matrix. 10,000 UFB replicates were run. The BI analysis was performed in RevBayes (Höhna et al., 2016) but was unable to attain acceptable convergence levels, therefore results are not presented in the present work.

Results

Morphological phylogenetics

Both morphological ML and BI analyses recovered trees with low supported clades and several polytomies (Supp. Figs. 1 (ML) and 2 (BI)). In the ML analysis the genera *Choeradoplana*, *Cephaloflexa*, *Xerapoa, Matuxia, Luteostriata, Issoca, Imbira, Pasipha, Gusana,* and *Notogynaphallia* were retrieved as monophyletic, whereas *Cratera*, *Obama*, and *Paraba* resulted in non-monophyletic groupings.

The BI resulted in a very low supported phylogeny presented as a general polytomy, showing monophyly for the genera *Gusana, Matuxia, Notogynaphallia, Issoca, Luteostriata, Imbira, Choeradoplana, Cephaloflexa,* and *Xerapoa*. All other genera were retrieved as non-monophyletic groupings. *Choeradoplana* appears as the

sister group of *Cephaloflexa* with high PP values, and is sister to *Xerapoa* in both analyses, ML and BI. All other clades show low PP values.

Individual gene performance

We tried to obtain full representation of all genes included in the study, but it was not possible in some cases, being DOM5 and Tnuc813 the genes with less representation (with a 33.8% and 52% of the species represented in the study, respectively), and COI and 18S having the highest representation (with a representation of 88.3% and 92.9%, respectively). Saturation tests showed that the third codon position of COI alignment for each dataset was not saturated.

Single-gene analyses retrieved trees with only similarity in the gross topology since they vary in the interrelationships of the genera and deeper nodes (Supp. Figs. 3-8). The three clades grouping different genera that were most frequently recovered are: 1) *Issoca* + *Luteostriata* + *Supramontana*, 2) *Choeradoplana* + *Cephaloflexa,* and 3) *Obama* + *Cratera*. These groups nonetheless have very low UFB (<70%) for some genes. The best resolution was obtained with 28S (Supp. Fig. 3), EF (Supp. Fig. 4) and Tnuc813 (Supp. Fig. 7). These three markers recovered the highest number of supported nodes, even the ancient ones, whereas those inferred from the nuclear region DOM5 showed low support values for almost all deep nodes.

Some terminals show relatively long branches in some of the phylogenies, such as the case of *Paraba multicolor a* for Tnuc813.

Analysis of the concatenated dataset

With both optimality criteria (ML, IB), the concatenated dataset generated two topologically similar phylogenies with almost the same support values for the clades. The ML approach (Supp. Fig. 9) recovered the monophyly of all genera except for *Paraba, Imbira Luteostriata* and *Issoca. Paraba* is polyphyletic with its two species (*P.*

multicolor and *P. franciscana*) in different clades. The non-monophyletic status of *Imbira*, with six terminals, is caused by *Imbira* sp. 1, which is nested in the clade *Geoplana* + *Barreirana*. *Luteostriata* is paraphyletic because the species *Issoca jandaia* is included inside the clade.

The BI approach (Supp. Fig. 10) shows all monophyletic genera except for *Paraba, Imbira*, *Luteostriata* and *Issoca*. The same situations are observed for the non-monophyly of these genera as in the previously interpreted ML phylogeny.

Total evidence phylogeny

The resulting alignment of the dataset presented a total of 5451 columns (5414 nucleotide positions and 37 morphological characters), from which 2387 presented distinct patterns, 1509 were parsimony-informative, 594 singletons and 3300 constant sites. In the phylogenetic tree (Fig. 1, ML) all genera are monophyletic except for *Issoca, Luteostriata, Paraba* and *Imbira*, respectively. In the following we describe the topology and support obtained from the ML analysis. Clade A is composed by all representatives of *Issoca*, *Luteostriata, Pasipha, Geobia,* and *Supramontana,* the latter three mentioned genera being monophyletic. *Issoca* was recovered as a polyphyletic genus as *Issoca jandaia* is found inside the *Luteostriata* clade, hence presenting a paraphyletic status. This whole clade A is sister to clade B with a low support value.

Clade B is composed by all the representatives of *Cratera*, *Obama* and *Gigantea* and shows high support value. The three genera are monophyletic. Clades A + B are the sister group to C + D. Clade C includes all *Imbira* species, except for *Imbira* sp. 1 which is positioned inside Clade D, and *Imbira* sp. 4, nested inside Clade H. Clade D contains the one species of *Barreirana* included in the study and *Geoplana boraceia*, apart from the already mentioned *Imbira* sp. 1. The sister clade to the polytomy (A + B) + C + D is clade E.

Clade E is composed of five monophyletic genera, namely *Choeradoplana, Cephaloflexa, Notogynaphallia, Xerapoa* and *Matuxia*, all supported by high UFB values (except for the sister relationship between *Xerapoa* and *Notogynaphallia*). Clade F includes two paraphyletic branches with terminals belonging to the two species of the genus *Paraba.*Clade G is composed of the monophyletic genus *Gusana,* grouped together with a high support value.

The following clade H is composed by *Imbira* sp. 4 and by "*Geoplana" quagga* and is sister to the remaining Geoplaninae with high support. A-H clade interrelationships are highly supported only for the most ancient internal nodes, i. e., H + sister clade and G + sister clade.

Discussion

Improvements of the Total Evidence phylogeny

The TE phylogenetic tree entails progress with respect to previous comprehensive contributions (Grau, 2010; Carbayo et al., 2013, Amaral, 2017; Negrete et al. 2019) in that the representativeness of each genus has increased, the number of species is also higher and two sources of data (i.e., morphology and molecular) are covered. Furthermore, differently from previous trees, most clades are well supported. Even though some genera, such as *Bogga, Difroehlichia, Liana, Pichidamas*, and *Piima,* still remain unrepresented in the analyses. Likewise *Polycladus*, *Wallamapuplana, Inkayalia,* and *Winsoria* were not included in this study to avoid eventual artifacts caused by missing data (sequence genes available on GenBank match only partially the ones used in this study).

TE produced the best-resolved hypothesis so far for the phylogeny of Geoplaninae despite some partitions are lacking in some terminals (e. g., Tnuc813 and DOM5) and some morphological character states remain unknown for some species (e. g., *Cratera*

pseudovaginuloides, *Pasipha tapetilla*). It has been demonstrated that different sources of information (higher numbers of molecular markers, morphological characters or terminals) increase tree robustness even when the sources of characters are incomplete (e.g., Bremer et al., 1999; Slowinski et al., 2002; Wiens, 2005; Álvarez-Presas et al., 2008). This may explain the higher robustness of the present study when compared with every single-gene phylogeny and morphology-based tree inferred in this work.

Interestingly, two of the best represented genes in our analyses, COI and 18S (each with a representation of 88.3% and 92.9% of the terminals, respectively) show the lowest support values and fewer number of monophyletic genera, contrasting with conclusions obtained in previous studies in which high representativeness for different genes retrieved the phylogenies with higher support values (e.g. Bremer et al., 1999; Murrell et al., 2001). A previous planarian phylogeny utilizing the COI and 18S molecular markers revealed that they are not as informative for older relationships, due to its high variability and high levels of saturation (Álvarez-Presas et al., 2008).

The general low support values of the trees inferred from the morphological data may be due to: a low number of characters, 37, with respect to the number of terminals (45 taxa) (Scotland et al., 2003); missing data; and a low number of terminals selected as outgroup, namely only two species (*Anzoplana trilineata* and *Endeavouria septemlineata*). Accordingly, outgroups with multiple representatives allow a more severe test of phylogenetic relationships and should produce a more stable ingroup topology with higher support values (Nixon and Carpenter, 1993; Puslednik and Serb, 2008; Wilberg, 2015; Grant, 2019; Medlin and Desdevises, 2020). *Endeavouria septemlineata* did not group up with the outgroup in the morphological BI analysis, either evidencing a weak selection of morphological characters for the analysis or evidencing this species as a bad choice as an Outgroup.

Land flatworms present some problems when carrying out molecular studies. Such problems are related to the availability of high amounts and the quality of purified

DNA, as in other animal groups. Planarians in general tend to yield poor quality DNA extractions, which is probably due to the presence of pigments that remain in the purified DNA interfering with the posterior amplifications to obtain the sequence data (Sluys and Riutort, 2018). Other difficulties are related to the primers available for Platyhelminthes. In other groups, many genes are amplified using universal primers which usually do not work on land planarian taxa (Sluys and Riutort, 2018). Such difficulties have created a slow income of molecular land flatworm studies and thus, up to date only one relatively comprehensive phylogeny of the Geoplaninae has been published (see Carbayo et al., 2013). Even with limited data, DNA sequences have proven to be useful and effective for solving land flatworm phylogenies at various levels of coverage and detail (Carbayo et al., 2013, 2018; Álvarez-Presas et al., 2008, 2014a, 2014b, 2015; Lemos et al., 2014; Rossi et al., 2016; Harrath et al., 2016; Almeida et al., 2019; Negrete et al., 2019; Lago-Barcia et al., 2015, 2018, 2021; Iturralde *et al*., 2021; Araújo et al., 2020).

Deeper morphological synapomorphies and homoplastic traits

The largest clades in the TE tree (namely clades A, B, and E) as well as the relationships within each large clade are overall congruent with previous studies and, more importantly, these clades are more robust in the TE tree. Alone these large clades stand for 13 of the 19 genera represented in the analyses. Clades A and B were recovered in the molecular inferences by Carbayo et al. (2013), whereas the clade E was retrieved with both molecular and morphological data by Grau (2010), Amaral (2017), Carbayo et al. (2013) and Rossi et al. (2019).

The major similarities between TE and Carbayo's et al. (2013) trees are the three large clades A, B, and E, (although only in Carbayo's trees the clades maintain sister relationships amongst them), the respective internal relationships, and the non-monophyletic status of *Issoca* and *Imbira* (see below).

Some suprageneric clades can be recognised with a set of morphological traits. The clade *Luteostriata* + members of *Issoca* + *Supramontana*, nested within clade A is supported by three synapomorphies, namely a ventro-cephalic glandular zone (indicated with an **a** on the tree, Fig. 1; convergent in *Choeradoplana*), a subneural parenchymatic musculature (**b**), and a fan-like cephalic retractor muscle (**c**). The non-monophyletic status of *Issoca* was also reported by Carbayo et al. (2013) and Negrete et al. (2019). Furthermore, Araujo & Carbayo (2018) showed morphological evidence for the polyphyletic status of *Issoca* and the genus is currently under review (unpublished).

All members of Clade B, namely *Cratera, Obama* and *Gigantea,* share two putative synapomorphies, i.e., a large, flattened, leaf-shaped body (**d**) and a large protrusible penis papilla (**e**), the latter character not coded in the morphological matrix.

The clade E, composed of *Cephaloflexa, Choeradoplana, Xerapoa, Notogynaphallia,* and *Matuxia*, is supported by a synapomorphic character state, i. e., the intrabulbar position of the prostatic vesicle (**f**). This character is absent in *Barreirana* and *Geoplana,* whose representatives lack this organ. Within the clade E the monophyletic group formed by *Cephaloflexa, Choeradoplana* is supported by three synapomorphies, namely a curled up cephalic extremity (**g**), loss (absence) of eyes in the anterior extremity of the body (**h**), a homoplastic attribute when *Imbira guaiana* is considered) and the loss (lack) of sensory pits in the anterior extremity of the body (**i**), all convergent in *Xerapoa*. The cephalic retractor muscle composed of muscle fibers parallel to the longitudinal body axis is a synapomorphy for the clade *Cephaloflexa* + *Choeradoplana* (**j**), whereas the loss (absence) of an ejaculatory duct is synapomorphic for the clade *Cephaloflexa, Choeradoplana, Notogynaphallia* and *Matuxia* (**k**). The ejaculatory duct was secondarily gained in *Xerapoa*.

From the TE tree, it emerges that most of the morphological characters traditionally used in the diagnoses of the genera are symplesiomorphic or suffered from homoplasy across Geoplaninae. For example, a body with parallel body margins, a wide

creeping sole, and eyes at the anterior extremity of the body seem to be symplesiomorphic. Other characters seem to be homoplastic: the cutaneous longitudinal muscle is partially insunk into the parenchyma in *Choeradoplana*, *Gusana* and *Supramontana*; the sub-neural parenchymatic muscle layer is restricted to only the cephalic extremity in *Cephaloflexa* + *Choeradoplana* and *Notogynaphallia*. Furthermore, *Pasipha, Gigantea,* and *Gusana* present a ventral female genital canal; *Pasipha* and *Notogynaphallia* present a penis without a penis papilla; the prostatic vesicle is intrabulbar in *Barreirana*, *Cephaloflexa*, *Choeradoplana*, *Matuxia*, and *Notogynaphallia*. *Choeradoplana* and *Issoca* have a cephalic extremity laterally expanded, although the cephalic shape differs in the details. *Gusana, Gigantea, Pasipha* and *Xerapoa* present ovoviteline ducts in the post-flex condition.

Little is known on evolution of character states in land planarians conducted with rigorous tests (Ogren & Sluys, 1998). Cases of convergent, reverse, and parallel evolution are documented among triclads and other members of the platyhelminths at various taxonomic ranks (e.g., Sluys, 1989; Littlewood et al., 1999) and this study supports the occurrence of these types of trait evolution within Geoplaninae.

Doubtful phylogenetic interrelationships

The TE tree retrieved three unexpected taxonomic groupings. *Imbira* is strikingly polyphyletic, with *Imbira* sp. 1 sharing a sister-group relationship with *Barreirana* + *Geoplana* (Clade D), and *Imbira* sp. 4 nested within the Clade H ("*Geoplana" quagga* clade), i.e., both species are nested out of the clade C. The apparent polyphyly of this genus is in disagreement with the morphological information, as the species *Imbira* sp. 4, presents the diagnostic characters of *Imbira*, including the longitudinal parenchymatic muscle only found in members of this genus. The polyphyletic position of *Imbira* sp. 1 is being addressed elsewhere due to a lack of morphological information.

Paraba is polyphyletic and poorly supported. Some of the single-gene trees retrieved the genus as non-monophyletic as well. In Carbayo's et al. (2013) analyses *Paraba* was recovered as monophyletic in only some of the trees. Nonetheless, our analyses included only two of the 19 species of the genus and the poor representation of the group might have affected its polyphyletic status. Morphologically, *Paraba* is diagnosed with a combination of non-exclusive characters.

The phylogenetic position of *Imbira* members and species of *Paraba* remain an open question and no nomenclatural changes or generic definitions can be proposed based on our analyses. Hopefully additional evidence from more molecular markers and morphological data will shed light on their evolutionary interrelationships.

Final remarks

The analyses of our combined dataset - morphology + molecular - produced a new, better resolved phylogeny. Six molecular markers were used with the addition of the morphological data, which comprised just 1.5% of the total concatenated dataset (37 morphological characters, 2387 polymorphic nucleotide sites). Predominance of molecular characters over the morphological ones is common (e. g., Lee et al., 2013; Lee and Palci, 2015; O'Leary et al., 2013). Therefore, the topology was mainly dictated by the genetic information. This is understandable since some diagnostic traits of the Geoplaninae genera were revealed as homoplastic. Some suprageneric clades can be diagnosed by morphological synapomorphies. In this study molecular synapomorphies were not explored as recently addressed (e.g., Trevisan et al., 2017; Almeida et al., 2019). Still, despite the challenges of assessing homology of morphological characters (e.g., Carranza et al., 1998; Scotland et al., 2013; Quiroga et al., 2015) the utilization of morphological data into a phylogenetic analysis will help understand the morphological changes that characterise the molecular groupings, and therefore help systematists to visualize and understand species and clades (Cantino and Queiroz, 2010; Lee and Palci,

2015). In this respect, the search for morphological characters, usually extracted from preserved animals and histological sections (either physical or virtual, for the later see micro Computed Tomography (mCT)) might be expanded to incorporate other techniques (see Wipfler et a., 2016 for prospects in insect phylogenetics). Increasing the number of characters usually also increases accuracy (Ney et al., 1983; Charleston et al., 1994). Hopefully, by combining an increased taxon sampling with a larger dataset of morphological and molecular characters, a fully resolved phylogeny will become a reality.

Traditional characters used to identify species at a genus level can be seen as homoplasies when analyzed at a more inclusive evolutionary level, such as the sub-family level. This observation strengthens the fact that convergence and regression are recurrent evolutionary processes, which have molded Geoplaninin evolution.

References

Almeida AL, Marques FP, Carbayo F. 2019. 'Endless forms most beautiful': taxonomic revision of the planarian Geoplana vaginuloides (Darwin, 1844) and discovery of numerous congeners (Platyhelminthes: Tricladida). *Zoological Journal of the Linnean Society* 185(1): 1-65.

Álvarez-Presas M, Baguñà J, Riutort M. 2008. Molecular phylogeny of land and freshwater planarians (Tricladida, Platyhelminthes): From freshwater to land and back. *Molecular Phylogeny and Evolution* 47: 555–568.

Álvarez-Presas M, Riutort M. 2014a. Planarian (Platyhelminthes, Tricladida) diversity and molecular markers: a new view of an old group. *Diversity* 6: 323–338.

Álvarez-Presas M, Sánchez-Gracia A, Carbayo F, Rozas J, Riutort M. 2014b. Insights into the origin and distribution of biodiversity in the Brazilian Atlantic forest hot-

spot: a statistical phylogeographic study using a low-dispersal organism. *Heredity* 112(6): 656-665.

Álvarez-Presas M, Amaral SV, Carbayo F, Leal-Zanchet AM, Riutort M. 2015. Focus on the details: morphological evidence supports new cryptic land flatworm (Platyhelminthes) species revealed with molecules. *Organisms Diversity & Evolution* 15(2): 379-403.

Amaral S. 2017. Taxonomia e filogenia de espécies de Geoplaninae (Platyhelminthes) com ênfase nos gêneros Pasipha Ogren & Kawakatsu, 1990 e Imbira Carbayo et al., 2013. Universidade do Vale do Rio dos Sinos (unpublished Ph.D. thesis).

Araujo APG, Carbayo F. 2018. A new species of the land planarian Issoca sheds light on the polyphyletic status of the genus (Platyhelminthes, Tricladida, Geoplaninae). *ZooKeys* (752): 1-15.

Araujo APG, Carbayo F, Riutort M, Álvarez-Presas M. 2020. Five new pseudocryptic land planarian species of Cratera (Platyhelminthes: Tricladida) unveiled through integrative taxonomy. *PeerJ* 8: e9726.

Baguñà J, Carranza S, Paps J, Ruiz-Trillo I, Riutort M. 2001. Molecular taxonomy and phylogeny of Tricladida. In: Littlewood DTJ, Bray RD (eds) Interrelationships of the Platyhelminthes. Taylor & Francis, London, England, pp 49–56.

Bremer B, Jansen R, Oxelman B, Backlund M, Lantz H, Kim KJ. 1999. More characters or more taxa for a robust phylogeny-case study from the Coffee family (Rubiaceae). *Systematic Biology* 48(3): 413-435. 10.1080/106351599260085.

Cabra-García J, Hormiga G. 2020. Exploring the impact of morphology, multiple sequence alignment and choice of optimality criteria in phylogenetic inference: a case study with the Neotropical orb-weaving spider genus *Wagneriana* (Araneae: Araneidae). *Zoological Journal of the Linnean Society* 188(4): 976–1151.

Cantino PD, de Queiroz K. 2010. The Phylocode: International Code of Phylogenetic Nomenclature. Version 4c. http://www.ohio.edu/phylocode/.

Carbayo, F. 2003. Revisión de *Notogynaphallia* (Platyhelminthes: Tricladida) Ogren & Kawakatsu, 1990. Universidad de Salamanca (unpublished Ph.D. thesis,).

Carbayo F, Álvarez-Presas M, Olivares CT, Marques FPL, Froehlich EM, Riutort M. 2013. Molecular phylogeny of Geoplaninae (Platyhelminthes) challenges current classification: proposal of taxonomic actions. *Zoologica Scripta* 42:508–528.

Carbayo F, Silva MS, Riutort M, Álvarez-Presas M. 2018. Rolling into the deep of the land planarian genus Choeradoplana (Tricladida, Continenticola, Geoplanidae) taxonomy. *Organisms Diversity & Evolution* 18(2): 187-210.

Carranza S, Baguñà J, Riutort M. 1997. Are the Platyhelminthes a Monophyletic Primitive Group? An assessment using 18s rDNA sequences. *Molecular Biology and Evolution* 14(5): 485-497.

Carranza S, Littlewood DT, Clough KA, Ruiz-Trillo I, Baguñà J, Riutort M. 1998. A robust molecular phylogeny of the Tricladida (Platyhelminthes: Seriata) with a discussion on morphological synapomorphies. *Proceedings of the Royal Society B* 265:631–640.

Charleston MA, Hendy MD, Penny D. 1994. The effects of sequence length, tree topology, and number of taxa on the performance of phylogenetic methods. *Journal of Computational Biology.* 1:133-151.

Du C, Chen J, Jiang L, Qiao G. 2021. Phylogeny of *Drepanosiphine* aphids sensu lato (Hemiptera, Aphidoidea) inferred from molecular and morphological data. *Current Zoology* 1–13. doi: 10.1093/cz/zoab009

Eernisse DJ, Kluge AG. 1993. Taxonomic Congruence versus Total Evidence, and Amniote Phylogeny Inferred from Fossils, Molecules, and Morphology. *Mol. Bid. Ed.* 10(6): 1170- 1195.

Frías-López C, Sánchez-Herrero JF, Guirao-Rico S, Mora E, Arnedo MA, Sánchez-Gracia A, Rozas J. 2016. DOMINO: development of informative molecular markers for phylogenetic and genome-wide population genetic studies in non-model organisms. *Bioinformatics* 32(24): 3753-3759.

Froehlich CG. 1967. A contribution to the zoogeography of Neotropical land planarians. *Acta Zoologica Lilloana* 23: 153-162.

Giribet G, Carranza S, Baguna J, Riutort M, Ribera C. 1996. First molecular evidence for the existence of a Tardigrada + Arthropoda clade. *Molecular Biology and Evolution* 13(1): 76-84.

Graff LV. 1896. Ueber die Morphologie des Geschlechtsapparates der Landplanarien. *Verhandllungen der Deutchen Zoologishen Gesellschaft* 6: 75-93.

Graff LV. 1899. Monographie der Turbellarien. II. Tricladida Terricola (Landplanarien). I–XII. Atlas von Achtundfünfzig Tafeln zur Monographie der Turbellarien II. Tricladida Terricola (Landplanarien). Pls I–LVIII. Wilhelm Engelmann, Leipzig, 574 pp.

Grant T. 2019. Outgroup sampling in phylogenetics: severity of test and successive outgroup expansion. *Journal of Zoological Systematics and Evolutionary Research* 57(4): 748-763.

Grau JH. 2010. Relações filogenéticas entre os gêneros de Geoplaninae (Platyhelminthes, Tricladida) inferidas de caracteres morfológicos. Universidade de São Paulo, São Paulo, Brazil. (Unpublished Master Project).

Hall TA. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. In *Nucleic acids symposium series* Vol. 41, No. 41, pp. 95-98. London: Information Retrieval Ltd., c1979-c2000.

Hallez, P. 1892. Catalogue des Turbellariés (Rhabdocoelides, Triclades et Dendrocoelides) du Nord de la France & de la Cote Boulonnaise. *Rev. Biol. Nord. Fra.* 4: 301–326. 338–350. 425–456.

Hallez P. 1893. Catalogue des Turbellariés (Rhabdocoelides, Triclades et Dendrocoelides) du Nord de la France & de la Cote Boulonnaise. *Rev. Biol. Nord. Fra.* 5: 92–107. 135–145.

Hallez, P. 1894. Catalogue des Rhabdocoelides, Triclades & Polyclades du Nord de la France, 2nd, 239 Lille, France: L. Daniel. + 2 pls

Harrath AH, Mansour L, Lagnika M, Sluys R, Boutin C, Alwasel S, …, Riutort M. 2016. A molecular analysis of the phylogenetic position of the suborder Cavernicola within the Tricladida (Platyhelminthes), with the description of a new species of stygobiont flatworm from Benin. *Zoological Journal of the Linnean Society* 178(3): 482-491.

Höhna S, Landis MJ, Heath TA, Boussau B, Lartillot N, Moore BR, …, Ronquist F. 2016. RevBayes: Bayesian Phylogenetic Inference Using Graphical Models and an Interactive Model-Specification Language. *Systematic Biology* 65(4): 726-736. https://doi.org/10.1093/sysbio/syw021

Iturralde GG, Allgayer H, Valiati VH, Leal-Zanchet AM. 2021. Seeing the true colours: three new species of *Obama* (Platyhelminthes: Continenticola) from remnants of Atlantic forest in southern Brazil based on an integrative approach. *Invertebrate Systematics* 35(3): 312-331.

Jenner RA. 2004. Accepting Partnership by Submission? Morphological Phylogenetics in a Molecular Millennium. *Systematic Biology* 53(2): 333-342. DOI:101080/10635150490423962

Katoh K, Standley DM. 2013. MAFFT multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology and Evolution* 30(4), 772-780.

Kluge A. 2004. On total evidence: for the record. *Cladistics* 20: 205–207.

Kluge A. 2009. Explanation and falsification in phylogenetic inference: exercises in Popperian philosophy. *Acta Biotheoretica* 57: 171–186.

Lago-Barcia D, Fernández-Álvarez FA, Negrete L, Brusa F, Damborenea C, Grande C, Noreña C. 2015. Morphology and DNA barcodes reveal the presence of the non-native land planarian Obama marmorata (Platyhelminthes: Geoplanidae) in Europe. *Invertebrate Systematics* 29: 12–22.

Lago-Barcia D, Carbayo F. 2018. Taxonomic revision of four species of the Neotropical land planarian genera Cratera and Geoplana (Platyhelminthes, Tricladida) with a description of two new species and an emendation of Cratera. *Zootaxa* 4500(4): 517–542 https://doi.org/10.11646/zootaxa.4500.4.3 PMID: 30486048.

Lago-Barcia D, Silva MS, Carbayo F. 2021. Revision and description of six species of Choeradoplana (Platyhelminthes, Tricladida), with an emendation to the genus. *ZooKeys* 1016: 1-48.

Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott B. 2017. PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. *Molecular Biology and Evolution* 34(3): 772-773.

Lázaro EM, Sluys R, Pala M, Stocchino GA, Baguña J, Riutort M. 2009. Molecular barcoding and phylogeography of sexual and asexual freshwater planarians of the genus Dugesia in the Western Mediterranean (Platyhelminthes, Tricladida, Dugesiidae). *Molecular Phylogenetics and Evolution* 52: 835–845.

Lee MSY, Palci. 2015. Morphological Phylogenetics in the Genomic Age. *Current Biology* 25(19): 922-929. http://dx.doi.org/10.1016/j.cub.2015.07.009

Lee MSY, Soubrier J, Edgecombe GD. 2013. Rates of phenotypic and genomic evolution during the Cambrian explosion. *Current Biology* 23: 1889–1895.

Lemey P, Salemi M, Vandamme AM. 2009. The Phylogenetic Handbook: a practical approach to phylogenetic analysis and hypothesis testing, 2nd edn. Cambridge University Press, Cambridge.

Lemos VSA, Cauduro GPB, Valiati HV, Leal-Zanchet AM. 2014. Phylogenetic relationships within the flatworm genus Choeradoplana Graff (Platyhelminthes: Tricladida) inferred from molecular data with the description of two new sympatric species from Araucaria moist forests. *Invertebrate Systematics* 28(6): 605-627.

Littlewood DTJ, Bray RA, Clough KA. 1998. A phylogeny of the Platyhelminthes: towards a total-evidence solution. *Hydrobiologia* 383: 155–160.

Littlewood DTJ, Rohde K, Clough KA. 1999. The interrelationships of all major groups of Platyhelminthes: phylogenetic evidence from morphology and molecules. *Biological Journal of the Linnean Society* 66: 75–114.

Marcus E. 1953. Turbellaria Tricladida. In: Exploration du Parc National de l'Upemba. Mission GF De Witte (1946-1949). *Inst Parcs Nationaux du Congo Belge* 21: 3-62.

Meacham CA. 1986. More about directed characters: a reply to Donoghue and Maddison. *Taxon* 35: 538-540.

Medlin LK, Desdevises Y. 2020. Phylogenetic reconstruction of diatoms using a seven-gene dataset, multiple outgroups, and morphological data for a total evidence approach. *Phycologia* 59(5): 422-436.

Meixner J. 1928. Der genitalapparat der tricladen und seine beziehungen zu ihrer allgemeinen morphologie, philogenie, okologie und verbreitung. *Zeitschr. Morphol. Okol.* 11: 570–612.

Miller MA, Pfeiffer W, Schwartz T. 2010 "Creating the CIPRES Science Gateway for inference of large phylogenetic trees" in Proceedings of the Gateway Computing Environments Workshop (GCE), New Orleans, LA pp 1 – 8.

Morales CH, Sturaro MJ, Sales Nunes PM, Lotzkat S, Peloso PLV. 2020. A species-level total evidence phylogeny of the microteiid lizard family Alopoglossidae (Squamata: Gymnophthalmoidea). *Cladistics* 1–21. DOI: 10.1111/cla.12407

Murrell A, Campbell NJH, and Barker SC. 2001. *Molecular Phylogenetics and Evolution* 21(2): 244–258. doi:10.1006/mpev.2001.1018

Negrete L, Amaral SV, Ribeiro GG, Gonçalves JW, Valiati VH, Damborenea C, Brusa F, Leal-Zanchet AM. 2020. Far away, so close! Integrative taxonomy reveals a new genus and species of land flatworm (Platyhelminthes: Geoplanidae) from southern South America *Zoological Journal of the Linnean Society* 189(3): 722–744, https://doi.org/10.1093/zoolinnean/zlz131

Nei M, Tajima F, Tateno Y. 1983. Accuracy of estimated phylogenetic trees from molecular data. II. Gene frequency data. *Journal of Molecular Evolution* 19: 153-170.

Nguyen LT, Schmidt HA, Von Haeseler A, Minh BQ. 2015. IQ-TREE: a fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. *Molecular Biology and Evolution* 32(1): 268-274.

Nixon KC, Carpenter JM. 1993. On outgroups. *Cladistics* 9: 413-426.

Nixon KC, Carpenter JM. 1996. On simultaneous analysis. *Cladistics* 12(3): 221-241. https://doi.org/10.1006/clad.1996.0016.

Ogren RE, Sluys R. 1998. Selected characters of the copulatory organs in the land planarian family Bipaliidae and their taxonomic significance (Tricladida: Terricola). *Hydrobiologia* 383: 77–82.

O'Leary MA, Bloch JI, Flynn JJ, Gaudin TJ, Giallombardo A, Giannini NB, Goldberg SL, Kraatz BP, Luo ZX, Meng J. 2013. The placental mammal ancestor and the post-K-Pg radiation of placentals. *Science* 339: 662–667.

Pantin CFA. 1953. On the name of the ground fluke *Fasciola terrestris* O. F. Müller, on *Othelosoma symondsi* Gray, and on the genus Amblyplana von Graff. *Journal of the Linnean Society of London*. *Zoology* (Jena, Germany) 42: 207–218.

Puslednik L, Serb JM. 2008. Molecular phylogenetics of the Pectinidae (Mollusca: Bivalvia) and effect of increased taxon sampling and outgroup selection on tree topology, *Molecular Phylogenetics and Evolution* 48: 1178-1188.

Quiroga SY, Carolina Bonilla E, Marcela Bolaños D, Carbayo F, Litvaitis MK, Brown FD. 2015. Evolution of flatworm central nervous systems. *Genetics and Molecular Biology* 38(3): 233-48. doi: 10.1590/S1415-475738320150013

Rambaut A, Drummond AJ. 2007. Tracer v1.7. <beast.bio.ed.ac.uk/Tracer>.

Rossi I, Amaral SV, Ribeiro GG, Cauduro GP, Fick I, Valiati VH, Leal-Zanchet AM. 2016. Two new Geoplaninae species (Platyhelminthes: Continenticola) from Southern Brazil based on an integrative taxonomic approach. *Journal of Natural History* 50(13-14): 787-815.

Rossi I, do Amaral SV, Ribeiro GG, Müller MJ, Valiati VH, Leal-Zanchet AM. 2019. Phylogenetic relationships within the flatworm genus Matuxia (Platyhelminthes, Tricladida, Continenticola) inferred from molecular data with the description of a southern lineage of the genus. *Organisms Diversity & Evolution* 19(3): 377-390.

Scotland RW, Olmstead RG, Bennett JR. 2013. Phylogeny Reconstruction: The Role of Morphology Systematics and Biology 52(4): 539-548.

Slowinski J, Lawson R. 2002. Snake phylogeny: evidence from nuclear and mitochondrial genes. *Molecular Phylogenetics and Evolution*. 24(2): 194-202. DOI: 10.1016/S1055-7903(02)00239-7.

Sluys R. 1989. Rampant Parallelism: An appraisal of the use of nonuniversal derived character states in phylogenetic reconstruction. *Systematic Zoology* 38(4): 350-370.

Sluys R, Riutort M. 2018, Planarian diversity and phylogeny. In: Rink, J.C. (Ed.), Planarian Regeneration. Humana Press, New York, New York, pp. 1–56. https://doi.org/10.1007/978-1-4939-7802-1₁

Talavera G, Castresana J. 2007. Improvement of phylogenies after removing divergent and ambiguously aligned blocks from protein sequence alignments. *Systematic Biology* 56(4): 564-577.

Trevisan B, Primon JF, Marques FPL. 2017. Systematics and diversification of Anindobothrium Marques, Brooks & Lasso, 2001 (Eucestoda: Rhinebothriidea). *PLoS ONE* 12: e0184632.

van Oppen M, McDonald B, Willis B, Miller D. 2001. The evolutionary history of the coral genus *Acropora* (Scleractinia, Cnidaria) based on a mitochondrial and a nuclear marker: reticulation, incomplete lineage sorting, or morphological convergence? *Molecular Biology and Evolution* 18(7): 1315-1329.

Wiens JJ. 2005. Can incomplete taxa rescue phylogenetic analyses from long-branch attraction? *Systematics Biology* 54(5): 731–742.

Winsor L, Johns PM, Yeates GW. 1998. Introduction, and ecological and systematic background, to the Terricola (Tricladida). *Pedobiologia* 42: 389–404.

Winsor L. 2003. Studies on the systematics and biogeography of terrestrial flatworms (Platyhelminthes: Tricladida: Terricola) of the Australian Region. James Cook University, Townsville. 439 pp (unpublished Ph.D. thesis).

Wipfler B, Pohl H, Yavorskaya MI, Beutel RG. 2016. A review of methods for analysing insect structures — the role of morphology in the age of phylogenomics. *Current Opinion in Insect Science* 18: 60–68. http://dx.doi.org/10.1016/j.cois.2016.09.004

Wilberg EW. 2015. What's in an Outgroup? The Impact of Outgroup Choice on the Phylogenetic Position of Thalattosuchia (Crocodylomorpha) and the Origin of Crocodyliformes. *Systematic Biology* 64(4): 621–637, https://doi.org/10.1093/sysbio/syv020

Xia X. 2018. DAMBE7: New and improved tools for data analysis in molecular biology and evolution. *Molecular Biology and Evolution* 35: 1550– 1552. https://doi.org/10.1093/molbe v/msy073

Figures

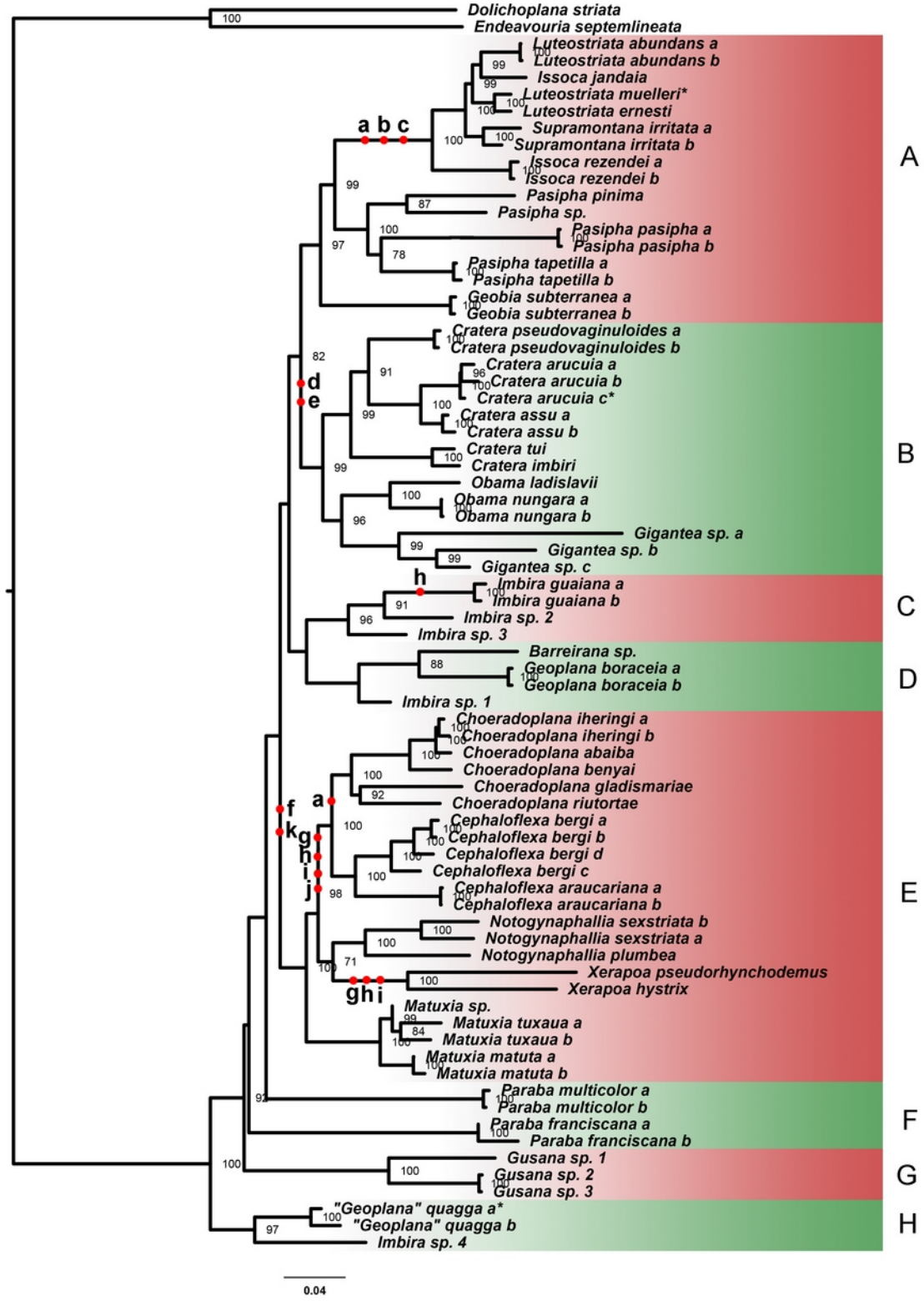

Dolichoplana striata
Endeavouria septemlineata
Luteostriata abundans a
Luteostriata abundans b
Issoca jandaia
Luteostriata muelleri*
Luteostriata ernesti
Supramontana irritata a
Supramontana irritata b
Issoca rezendei a
Issoca rezendei b
Pasipha pinima
Pasipha sp.
Pasipha pasipha a
Pasipha pasipha b
Pasipha tapetilla a
Pasipha tapetilla b
Geobia subterranea a
Geobia subterranea b
Cratera pseudovaginuloides a
Cratera pseudovaginuloides b
Cratera arucuia a
Cratera arucuia b
Cratera arucuia c*
Cratera assu a
Cratera assu b
Cratera tui
Cratera imbiri
Obama ladislavii
Obama nungara a
Obama nungara b
Gigantea sp. a
Gigantea sp. b
Gigantea sp. c
Imbira guaiana a
Imbira guaiana b
Imbira sp. 2
Imbira sp. 3
Barreirana sp.
Geoplana boraceia a
Geoplana boraceia b
Imbira sp. 1
Choeradoplana iheringi a
Choeradoplana iheringi b
Choeradoplana abaiba
Choeradoplana benyai
Choeradoplana gladismariae
Choeradoplana riutortae
Cephaloflexa bergi a
Cephaloflexa bergi b
Cephaloflexa bergi d
Cephaloflexa bergi c
Cephaloflexa araucariana a
Cephaloflexa araucariana b
Notogynaphallia sexstriata b
Notogynaphallia sexstriata a
Notogynaphallia plumbea
Xerapoa pseudorhynchodemus
Xerapoa hystrix
Matuxia sp.
Matuxia tuxaua a
Matuxia tuxaua b
Matuxia matuta a
Matuxia matuta b
Paraba multicolor a
Paraba multicolor b
Paraba franciscana a
Paraba franciscana b
Gusana sp. 1
Gusana sp. 2
Gusana sp. 3
"Geoplana" quagga a*
"Geoplana" quagga b
Imbira sp. 4
a b c
d e
f
k
g
h
i
j
a
g h i
A
B
C
D
E
F
G
H
0.04

Fig. 1. Maximum Likelihood inference phylogenetic tree inferred from the total evidence data matrix. Numbers at the nodes correspond to the ultrafast bootstrap values of the maximum likelihood analysis. Nodes with support values inferior to an 80% are not shown. Nodes missing in the ML analysis are shown by a '-'. Scale bar represents the estimated number of substitutions per site given an evolutionary model. Red circles in the branches show the gain of a character state, in green it shows reversion of the character state. **a** ventro-cephalic glandular zone, **b** subneural parenchymatic musculature, **c** fan-like cephalic retractor muscle, **d** large, flattened, leaf-shaped body, **e** large protrusible penis papilla, **f** intrabulbar position of the prostatic vesicle, **g** curled up cephalic extremity, **h** loss of eyes in the anterior extremity of the body, **i** loss (lack) of sensory pits in the anterior extremity of the body, **j** cephalic retractor muscle composed of muscle fibers parallel to the longitudinal body axis, **k** loss (absence) of an ejaculatory duct. * The individual is a molecular quimera.

Tables

Tab. 1. Species used in the study and their field code, GenBank accession numbers for all the sequences and Museum codes. '-' means nonexistent. 'x' means sequence obtained but not submitted to GenBank database. * Specimen is a molecular quimera with sequences obtained from 2 individuals.

Field Code number	Species	18S	28S	COI	EF	DOM5	Tnuc813	MZUSP PL
	Anzoplana tristriata	-	-	-	-	-	-	-
F1274	*Matuxia* sp.	x	-	-	-	x	x	-
F3931	*Barreirana* sp.	x	-	-	-	x	x	-
F3387	*Cephaloflexa araucariana* a	KC608550	KC608433	KC608316	KC614536	x	x	MZUSP PL 1073
F3426	*Cephaloflexa araucariana* b	KC608553	KC608436	KC608319	KC614539	-	-	MZUSP PL 1076
F1034	*Cephaloflexa bergi* a	KC608470	KC608353	KC608238	KC614472	-	x	MZUSP PL 303
F1038	*Cephaloflexa bergi* b	KC608472	KC608355	KC608240	KC614474	-	-	MZUSP PL 305
F3082	*Cephaloflexa bergi* c	-	-	KF971419	-	x	x	MZUSP PL 481
F5180	*Cephaloflexa bergi* d	-	-	x	-	x	x	MZUSP PL 1265
F3315	*Choeradoplana abaiba*	MF802576	-	HQ542891	-	-	x	MZUSP PL 511
F3494	*Choeradoplana benyai*	MF802589	MF802622	MF802640	MF802671	x	-	MZUSP PL 1163
F4217	*Choeradoplana riutortae*	x	-	x	-	x	x	MZUSP PL 1174
F3092	*Choeradoplana gladismariae*	KC608540	KC608423	KC608306	KC614528	-	-	MZUSP PL 1003
F0365	*Choeradoplana iheringi* a	MF802591	MF802624	MF802642	MF802673	-	-	MZUSP PL 651
F3449	*Choeradoplana iheringi* b	KC608554	KC608437	KC608320	KC614540	x	x	MZUSP PL 533
F2696	*Cratera arucuia* a	x		x	x	x	x	-
F2783	*Cratera arucuia* b	KC608513	KC608396	KC608281	KC614508	-	MT468607	MZUSP PL 1048
F3135_2784	*Cratera arucuia* c*	-	-	F2784	x	x	-	MZUSP PL 1065 / -
F2807	*Cratera assu* a	KC608516	KC608399	KC608284	KC614510	-	MT468609	MZUSP PL 1050
F2821	*Cratera assu* b	KC608519	KC608402	KC608287	KC614513	-	MT468611	MZUSP PL 1052
F5512	*Cratera imbiri*	MT441697	MT441720	MT437782	MT468589	-	MT468618	-
F1244	*Cratera pseudovaginuloides* a	KC608483	KC608366	KC608251	KC614482	-	MT468593	MZUSP PL 670
F1245	*Cratera pseudovaginuloides* b	KC608484	KC608367	KC608252	KC614483	x	MT468594	MZUSP PL 671
F2031	*Cratera tui*	KC608500	KC608383	KC608268	KC614497	-	MT468600	MZUSP PL 1014
F0379	*Dolichoplana striata*	KC608458	KC608341	KC608226	KC614465	-	-	MZUSP PL 1005
F0988	*Endeavouria septemlineata*	KC608465	KC608348	KC608233	KC614471	-	-	MZUSP PL 657
F0358	*Geobia subterranea* a	KC608457	KC608340	KC608225	KC614464	-	-	MZUSP PL 650
F1355	*Geobia subterranea* b	KC608487	KC608370	KC608255	KC614485	-	x	MZUSP PL 673
F4358	*Geoplana boraceia* a	KC608563	KC608446	KC608329	KC614547	-	x	MZUSP PL 1086

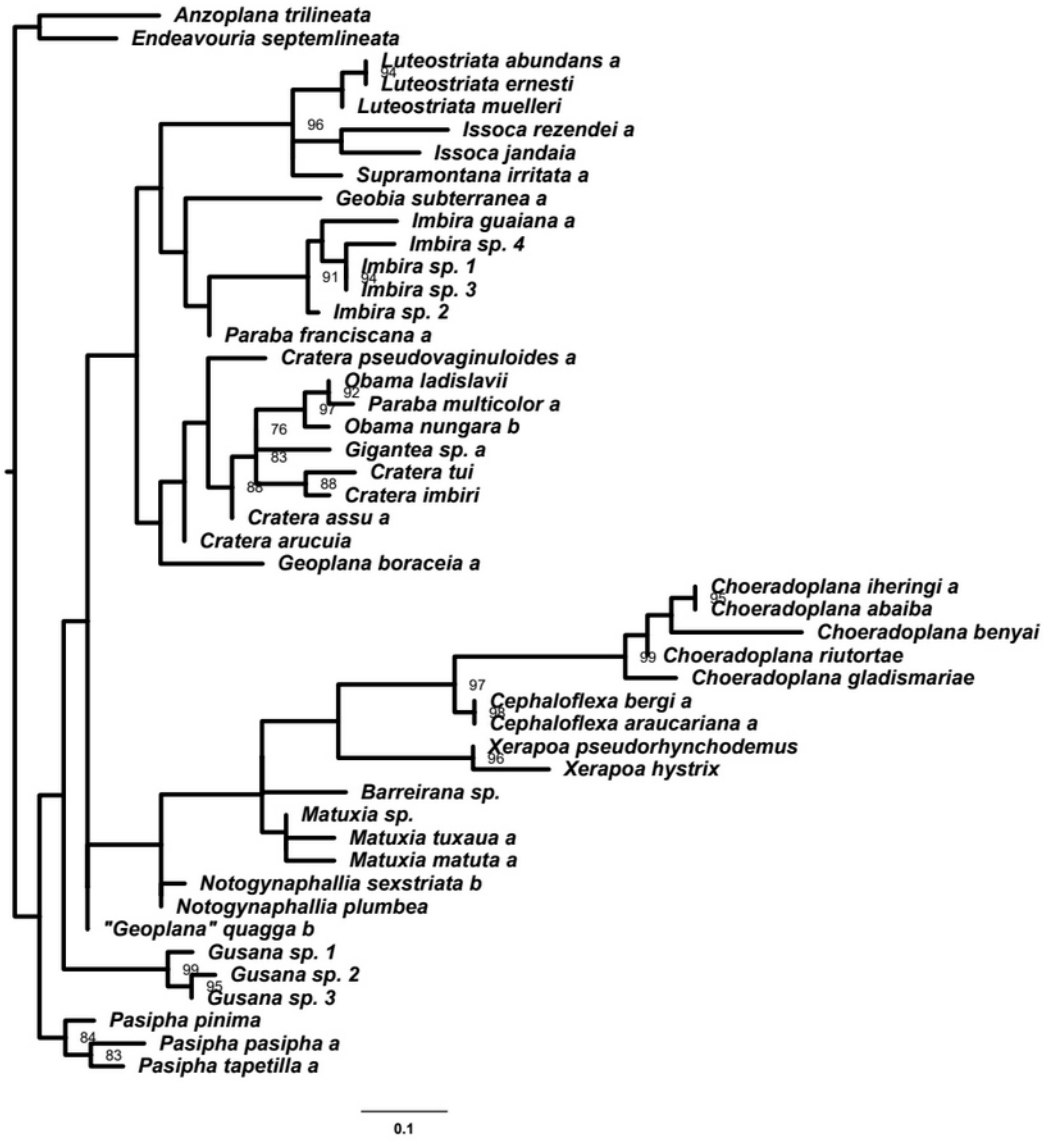
F2870	*Imbira* sp. 4	KC608526	KC608409	KC608294	-	-	-	MZUSP PL 412
F1003_1226	"*Geoplana" quagga* a*	KC608468	KC608351	F1226*	F1226*	-	-	MZUSP PL 1188 / MZUSP PL 591
F1736	"*Geoplana" quagga* b	KC608497	KC608380	KC608265	KC614495	-	x	MZUSP PL 594
F4409	*Geoplana boraceia* b	KC608564	KC608447	KC608330	KC614548	-	x	MZUSP PL 1087
F7514	*Gigantea* sp. a	18S1F7R	-	x	-	x	-	-
F7549	*Gigantea* sp. b	x	-	x	-	-	x	-
F7554	*Gigantea* sp. c	-	-	x	-	-	x	-
F4421	*Gusana* sp. 2	KC608565	KC608448	KC608331	KC614549	-	-	MZUSP PL 1088
F0395	*Gusana* sp. 1	x	-	-	-	x	x	-
F4428	*Gusana* sp. 3	KC608566	KC608449	KC608332	-	-	-	MZUSP PL 1089
F0432	*Imbira guaiana* a	KC608461	KC608344	HQ542894	KC614467	-	-	MZUSP PL 653
F3361	*Imbira guaiana* b	KC608548	KC608431	HQ542896	-	x	x	MZUSP PL 1071
F2833	*Imbira* sp. 2	KC608523	KC608406	-	KC614516	-	-	MZUSP PL 404
F5043	*Imbira* sp. 1	-	-	F5043*	-	F5043*	F5043*	MZUSP PL 1242
F5427	*Imbira* sp. 3	-	-	F5427*	-	F5427*	F5427*	MZUSP PL 1388
F2870	*Imbira sp. 4*	KC608526	KC608409	KC608294	-	-	-	-
F2043	*Issoca jandaia:* Carbayo et al., (2013)	KC608502	KC608385	KC608270	KC614498	-	x	MZUSP PL 1015
F1182	*Issoca rezendei* a	KC608480	KC608363	KC608248	KC614480	x	-	MZUSP PL 667
F1679	*Issoca rezendei* b	KC608495	KC608378	KC608263	KC614493	-	-	MZUSP PL 1010
F0205	*Luteostriata abundans* a	KC608455	KC608338	KC608223	KC614462	-	x	MZUSP PL 646
F0238	*Luteostriata abundans* b	KC608456	KC608339	KC608224	KC614463	-	-	MZUSP PL 648
F3358	*Luteostriata ernesti*	KC608547	KC608430	KC608313	KC614534	x	-	MZUSP PL 1070
F3268_0327	*Luteostriata muelleri**	KC608545	KC608428	KC608311	-	F0327*	F0327*	MZUSP PL 1199 / -
F2184	*Matuxia matuta* a	KC608508	KC608391	KC608276	KC614503	-	-	MZUSP PL 1021
F2187	*Matuxia matuta* b	KC608509	KC608392	KC608277	KC614504	-	x	MZUSP PL 1022
F1275	*Matuxia tuxaua* a	KC608485	KC608368	KC608253	-	-	-	MZUSP PL 1192
F3059	*Matuxia tuxaua* b	KC608536	KC608419	KC608302	KC614525	-	-	MZUSP PL 1058
F3072	*Notogynaphallia plumbea*	KC608537	KC608420	KC608303	KC614526	x	x	MZUSP PL 1060
F0792	*Notogynaphallia sexstriata* b	KC608464	KC608347	KC608232	KC614470	-	-	MZUSP PL 656
F1413	*Notogynaphallia sexstriata* a	KC608489	KC608372	KC608257	KC614487	x	x	MZUSP PL 680
F1418	*Obama ladislavii*	KC608490	KC608373	KC608258	KC614488	-	MT468597	MZUSP PL 681
F3191	*Obama nungara* a	KC608542	KC608425	KC608308	KC614530	-	-	MZUSP PL 1066
F3247	*Obama nungara* b	KC608543	KC608426	KC608309	KC614531	-	-	MZUSP PL 1067
F3357	*Paraba franciscana* a	KC608546	KC608429	KC608312	KC614533	x	x	MZUSP PL 1069
F5485	*Paraba franciscana* b	KC608569	KC608452	KC608335	KC614552	-	-	MZUSP PL 935
F2101	*Paraba multicolor* a	KC608503	KC608386	KC608271	KC614499	x	x	MZUSP PL 1017
F2997	*Paraba multicolor* b	KC608532	KC608415	KC608299	KC614521	-	-	MZUSP PL 1055
F1841	*Pasipha pasipha* a	KC608498	KC608381	KC608266	KC614496	-	-	MZUSP PL 1012
F2871	*Pasipha pasipha* b	KC608527	KC608410	KC608295	KC614518	-	x	MZUSP PL 1053
F1714	*Pasipha pinima*	KC608496	KC608379	KC608264	KC614494	x	x	MZUSP PL 1011

F2585	*Pasipha* sp.	KC608512	KC608395	KC608280	KC614507	-	-	MZUSP PL 717
F2878	*Pasipha tapetilla* a	KC608528	KC608411	KC608296	KC614519	x	x	MZUSP PL 732
F5631	*Pasipha tapetilla* b	KC608570	KC608453	KC608336	KC614553	-	-	MZUSP PL 938
F3453	*Supramontana irritata* a	KC608556	KC608439	KC608322	KC614542	x	x	MZUSP PL 772
F5483	*Supramontana irritata* b	KC608568	KC608451	KC608334	KC614551	-	-	MZUSP PL 937
F3057	*Xerapoa hystrix*	KC608535	KC608418	-	KC614524	-	x	MZUSP PL 1057
F1013	*Xerapoa pseudorhynchodemus*	KC608469	KC608352	KC608237	-	-	-	MZUSP PL 1189

Tab. 2. Primers used for the amplification of the DNA fragments.

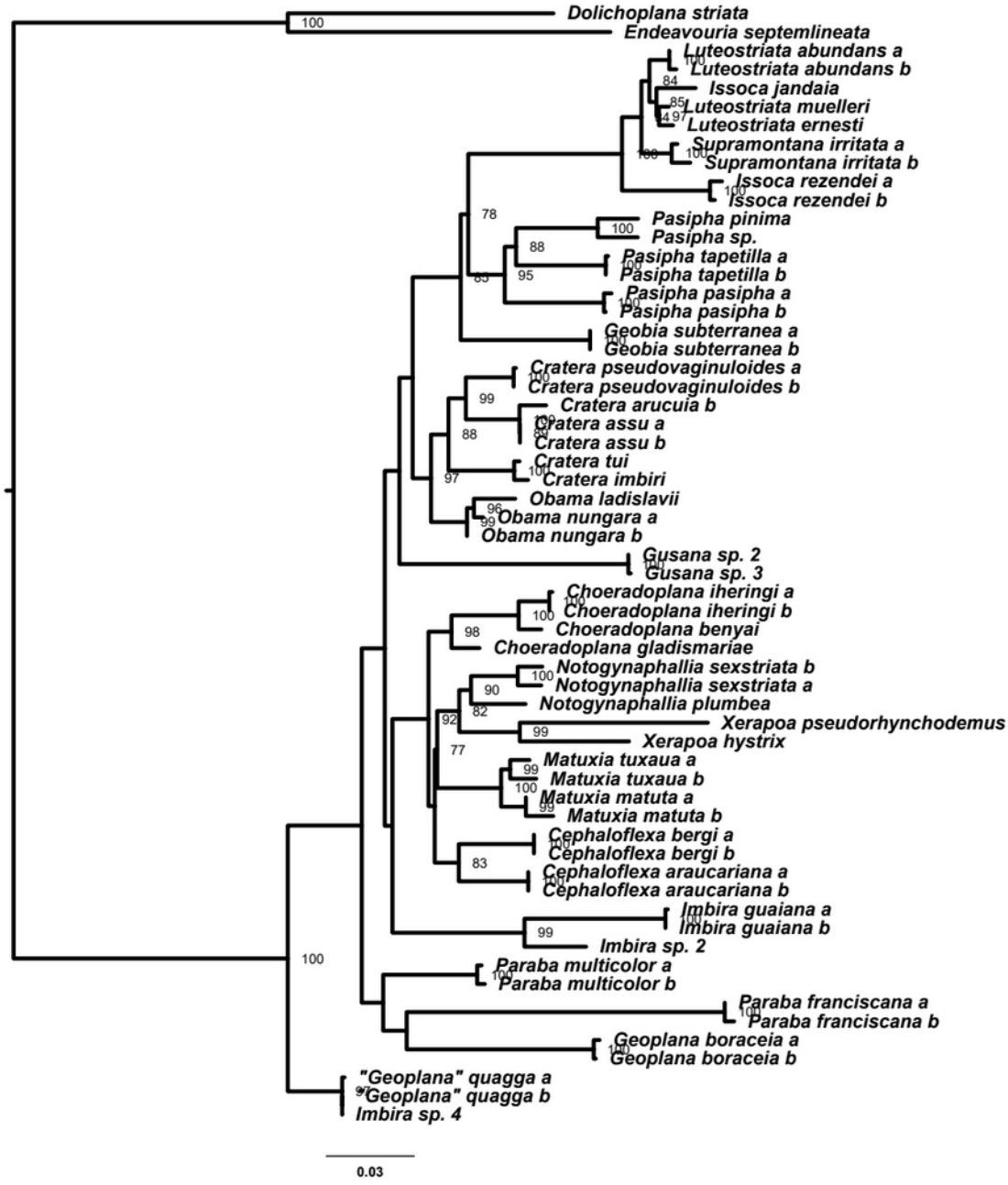
Target Locus	**Primer name (orientation)**	**Annealing temperature**	**Primer sequence**	**Reference**
28S rDNA	28S1F (forward)	52ºC	TATCAGTAAGCGGAGGAAAAG	Álvarez-Presas *et al.* 2008
	28S6R (reverse)	52ºC	GGAACCCCTTCTCCACTTCAGT	Álvarez-Presas *et al.* 2008
EF-1a	EFPlatF (forward)	48ºC	GATTGCYCCWGGYCATCG	Carbayo *et al.,* 2013
	EFPlatR (reverse)	48ºC	GCRATWGAYTCGTGRTGC	Carbayo *et al.,* 2013
18S rDNA type II	18S1F (forward)	45ºC	TACCTGGTTGATCCTGCCAGTAG	Giribet *et al.* 1996
	18S7R (reverse)	45ºC	GCATCACAGACCTGTTATTGC	Giribet *et al.* 1996
	18S4F (forward)	45ºC	CCAGCAGCCGCGCTAATTC	Giribet *et al.* 1996
	18S9R (reverse)	45ºC	GATCCTTCCGCAGGTTCACCTAC	Giribet *et al.* 1996
COI	BarS (reverse)	45ºC	GTTATGCCTGTAATGATTG	Álvarez-Presas *et al.,* 2011
	COIR (reverse)	45ºC	CCWGTYARMCCHCCWAYAGTAAA	Lázaro *et al.,* 2009
	COIF (forward)	45ºC	CCNGGDTTTGGDATDRTWTCWCA	Lázaro *et al.,* 2009
TNUC813	TNUCF6 (forward)	54ºC	CTTTGGGATACTGCTGG	Araujo *et al.,* 2020
	TNUCR6 (reverse)	54ºC	GCAAAACAAAACCAATCC	Araujo *et al.,* 2020
DOM5	DOM5F (forward)	54ºC	CTCCCTCGAACACTTGGATCA	This paper
	DOM5R (reverse)	54ºC	TGACAGTCAACGTCAAGCAAC	This paper

Supplementary Material

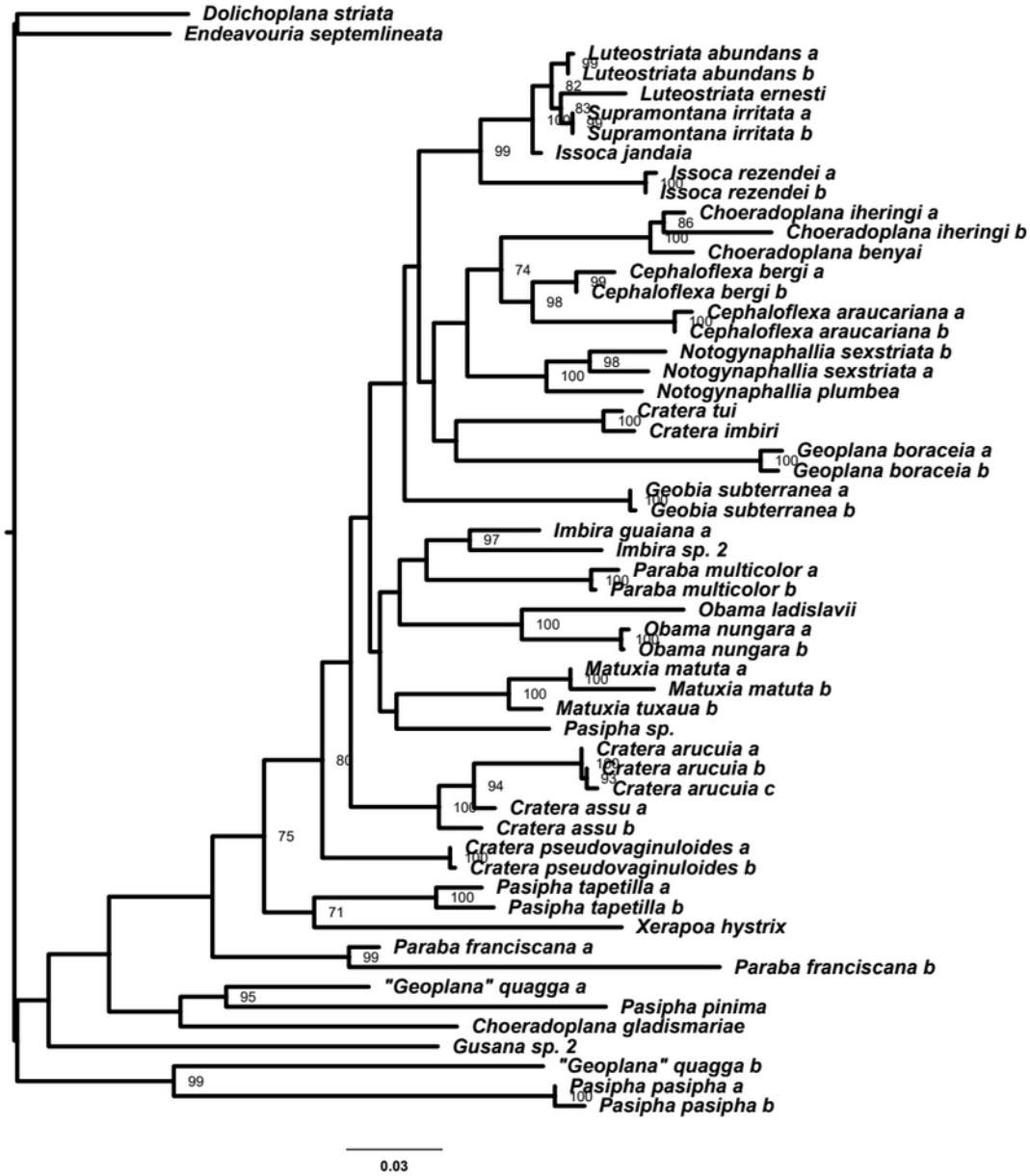


Supp. Fig. 1. Maximum Likelihood phylogenetic tree inferred from the morphological data. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents the estimated number of substitutions per site given an evolutionary model .

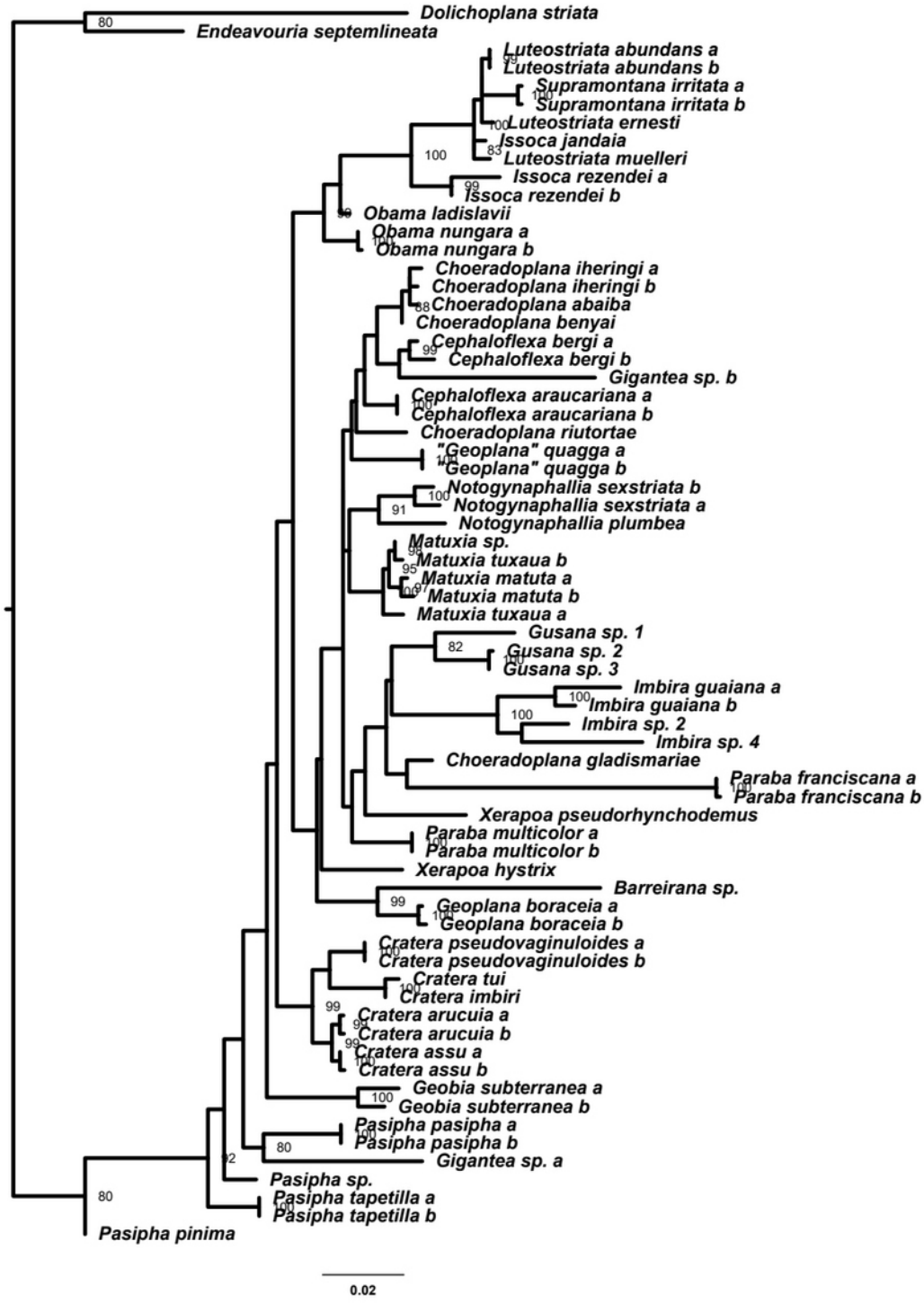
Supp. Fig. 2. Bayesian Inference phylogenetic tree inferred from the morphological data. Numbers over the nodes denote the posterior probability support obtained in the BI. Scale bar represents number of estimated substitutions per site given an evolutionary model .



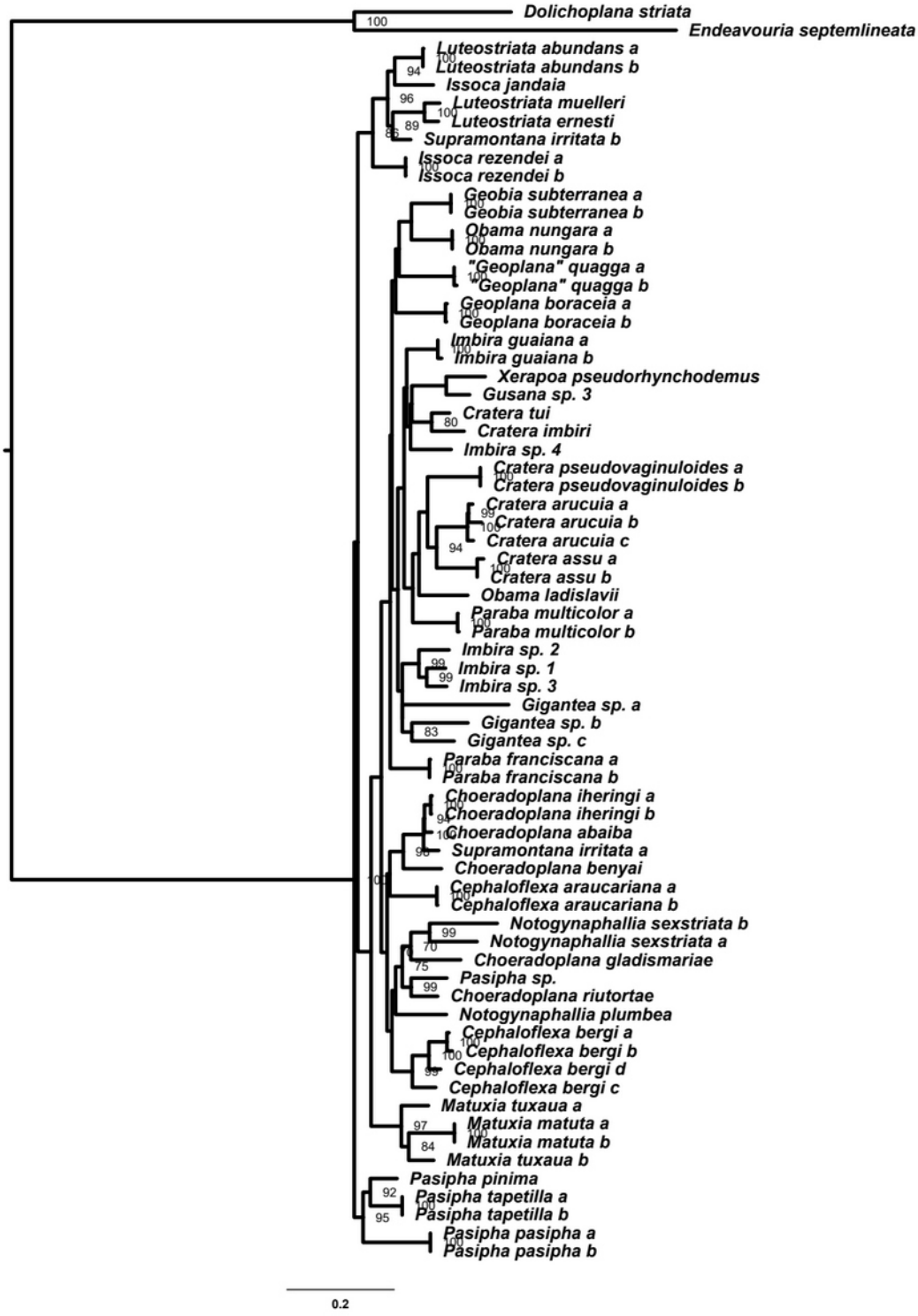
Supp. Fig. 3. Maximum Likelihood phylogenetic tree inferred from the 28S molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



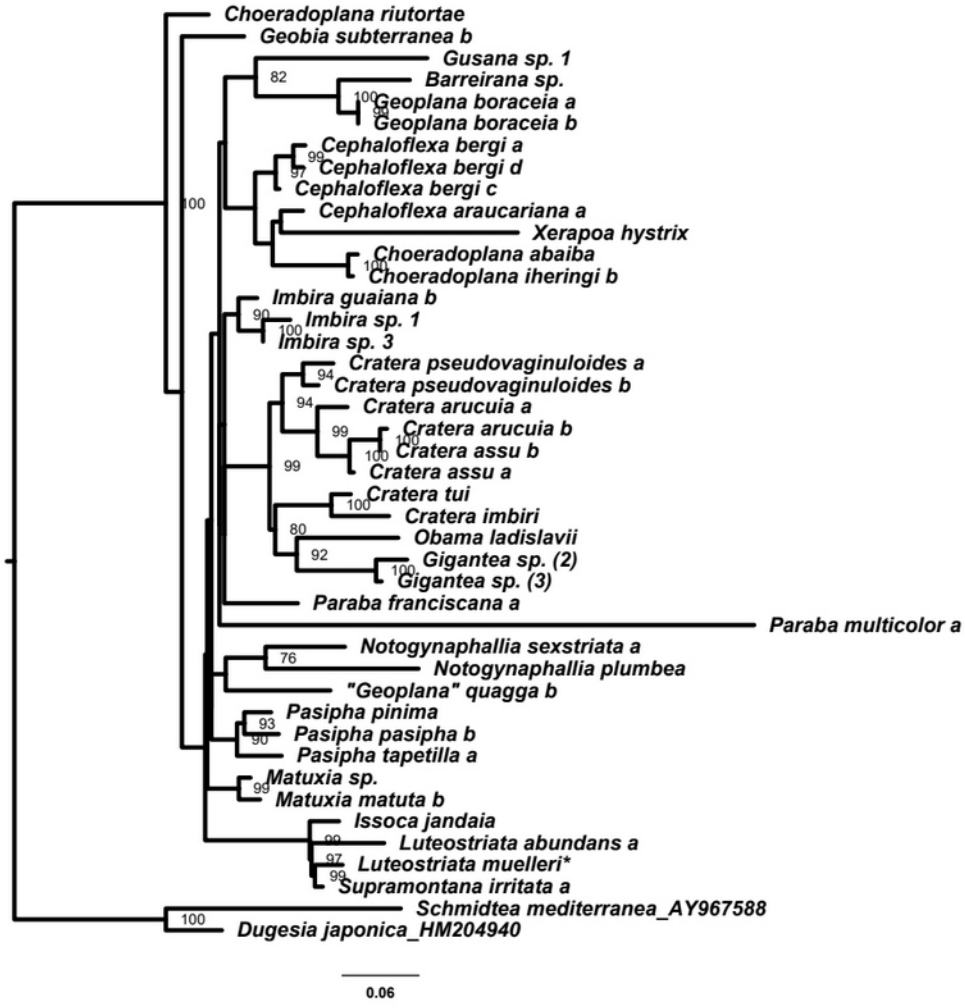
Supp. Fig. 4. Maximum Likelihood phylogenetic tree inferred from the EF molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



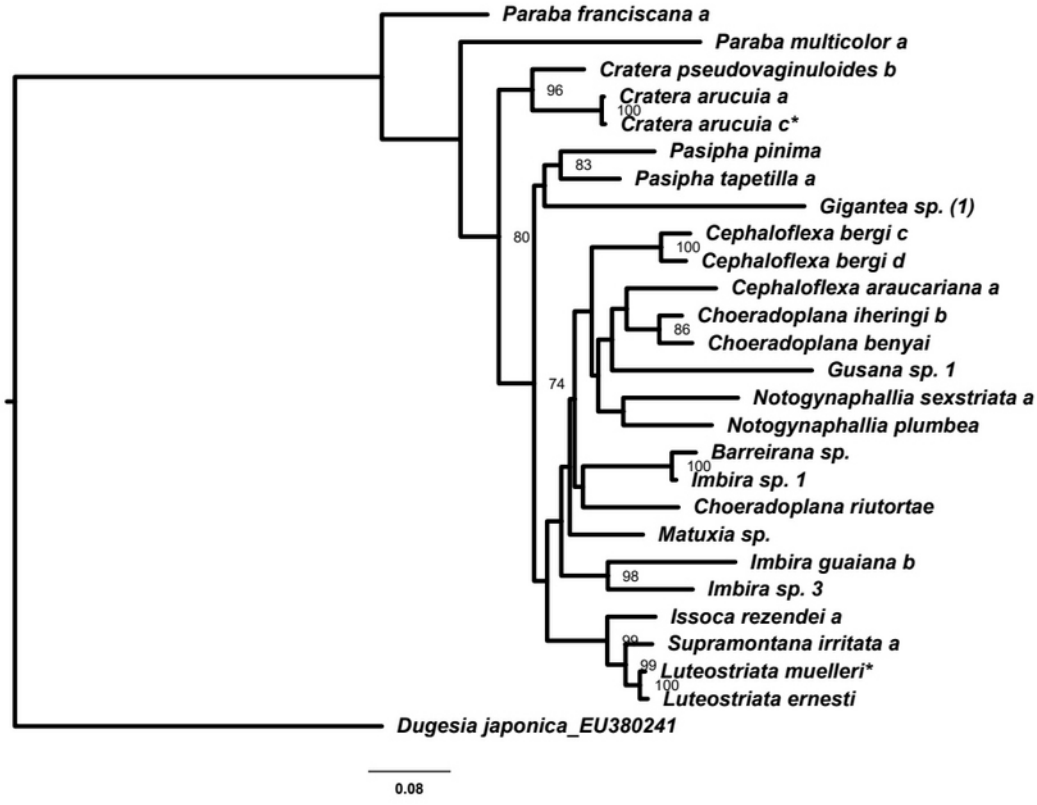
Supp. Fig. 5. Maximum Likelihood phylogenetic tree inferred from the 18S molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



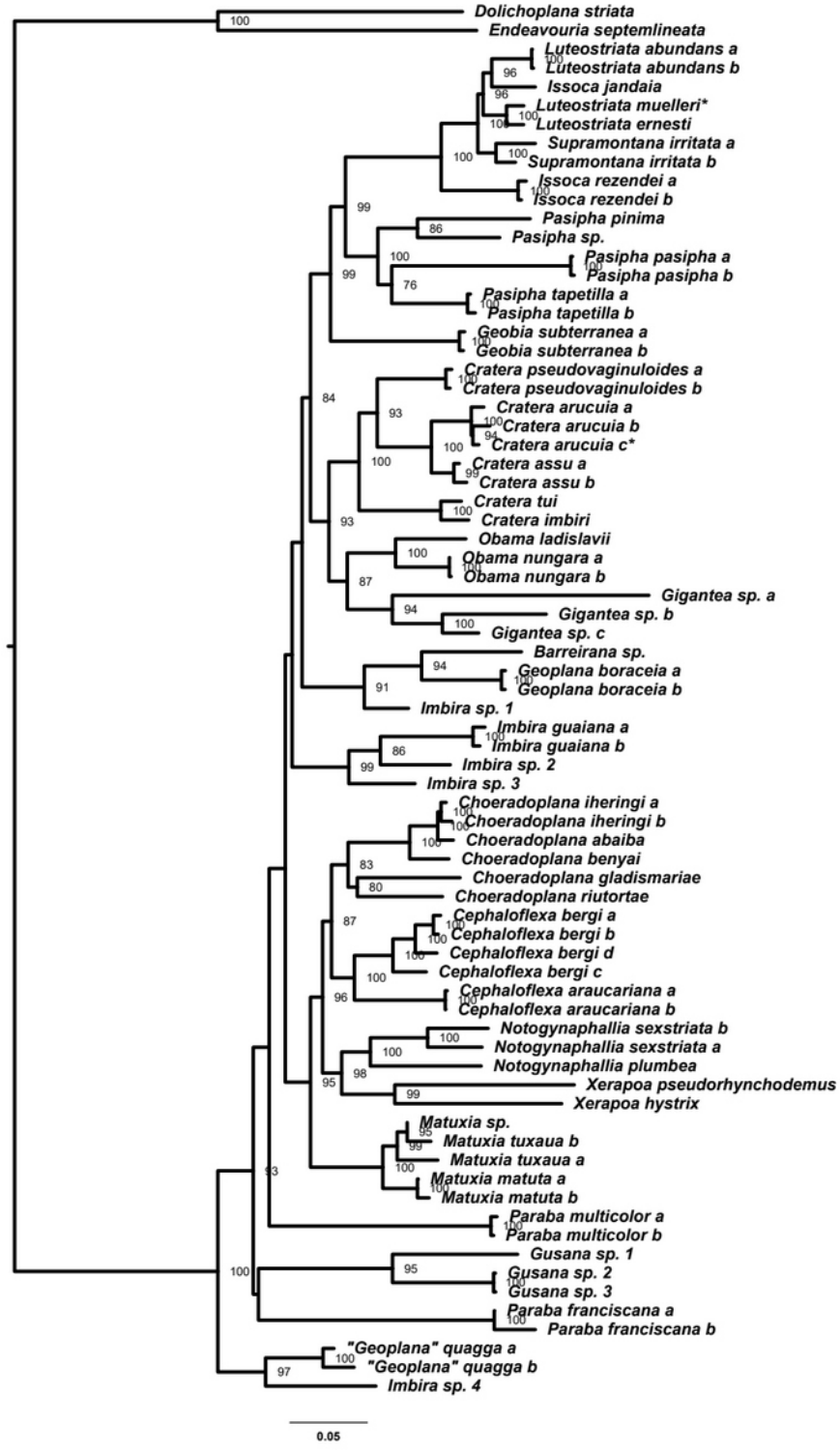
Supp. Fig. 6. Maximum Likelihood phylogenetic tree inferred from the COI molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



Supp. Fig. 7. Maximum Likelihood phylogenetic tree inferred from the Tnuc813 molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



Supp. Fig. 8. Maximum Likelihood phylogenetic tree inferred from the DOM5 molecular marker. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.



Supp. Fig. 9. Maximum Likelihood phylogenetic tree inferred from the ML molecular concatenated dataset. Numbers over the nodes denote the ultra fast bootstrap support values. Scale bar represents number of estimated substitutions per site given an evolutionary model.

Supp. Fig. 10. Bayesian Inference phylogenetic tree inferred from the BI molecular concatenated dataset. Numbers over the nodes denote the posterior probability support obtained in the BI. Scale bar represents number of estimated substitutions per site given an evolutionary model.

Supp. Tab. 1. Morphological matrix with all characters coded with their respective character states.

Species	Reference (Literature or our specimens) for morphology	General body shape		Cephalic extremity rounded and expanded laterally	Cephalic extremity with two cushions and expanded laterally	Cephalic extremity curled up	Creeping sole width		Trilobulated eyes		Number of eyes		Eyes at anterior extremity of the body	Eyes exclusively marginal	Sensory pits in anterior extremity of the body	Sensory pits branched	Sensory pits in double row along the body	Ventro-cephalic glandular zone	Glandular margin along the body	Cephalic retractor muscle of cutaneous fibers parallel to longitudinal body axis	Fan-shaped cephalic retractor muscle of cutaneous fibers	Sub-neural parenchymatic muscle		In cephalic extremity, sub-neural muscle fibers intermingled with those of ventral cutaneous muscle fibers	Cutaneous muscle partially *inwards ventrally* into parenchyma *along the body*	Cutaneous muscle partially *inwards dorsally* into parenchyma *along the body*	Cutaneous muscle partially *inwards ventrally* into parenchyma in *cephalic extremity*	Longitudinal parenchymatic muscle fibers present	Pharynx collar-shaped	Mouth in 4/4 of body length	Muscle fibers of internal epithelium of pharynx		Testes above supraintestinal parenchymatic muscle layer	Ovaries approximately leveled with anteriormost testes	Ovoviteline ducts approaching female atrium		Position of prostatic vesicle	Penis papilla type	Ejaculatory duct	Glandular ridges on penis papilla	Prostatic Vesicle bifurcated	Folded female atrium	Folded male atrium	Female atrium presents epithelium with stratified appearance (epitelio R)	Size of female atrium:size of male atrium Ratio
			lanceolate = 1	parallel body margins = 0	Yes = 1	No = 0	Yes = 1	No = 0	wide (>50%) = 1	narrow (<50%) = 0	Yes = 1	No = 0	**Absent = 2**	Multiple = 1	Two eyes = 0	**Zero = 2**	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0	No = 1	Yes = 0
			Only in cephalic region=1	**Along entire body=2**																		**Absent=0**																									

Cephaloflexa bergi a	2003 Carbayo & Leal-Zanchet, 2003	0	0	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1	1	1	1	0	1	0	1	0	1
Choeradoplana abaiba	Carbayo et al. 2017	0	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	0	1	1	0	1	2	0	0	1	1	1	1	0	0	1	1	0	1
Choeradoplana benyai	Lemos et al. 2014	0	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	0	1	1	0	1	2	0	0	0	1	0	0	0	0	1	0	1	0
Choeradoplana riutortae	F4217	0	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	0	1	1	0	1	2	0	0	1	1	1	1	0	0	0	1	0	0
Choeradoplana gladismariae	Carbayo & Froehlich, 2012	0	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	0	1	2	0	0	1	1	1	1	0	1	0	1	1	0
Choeradoplana iheringi a	Carbayo & Leal-Zanchet 2003; Carbayo et al. 2017	0	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	0	1	1	0	1	2	0	0	1	1	1	1	0	0	1	1	0	1
Cratera tui	Araujo et al. 2020	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1	1	0	1	2
Cratera arucuia	Lago-Barcia & Carbayo, 2018	1	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0
Cratera assu a	F2807; F28211	0	0	0	1	0	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	0	1	0	0	0
Cratera pseudovaginuloides a	Riester 1938; Froehlich 1956; F1245; F1244	1	0	0	0	1	0	1	0	0	?	1	1	1	0	?	?	0	0	0	0	0	1	0	1	?	0	?	1	1	0	0	0	0	0	0	0	0
Cratera imbiri	F5512	1	0	0	0	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	1	1	1	0	2
Geobia subterranea a	Schultze & Müller, 1875; Riester, 1938; Marcus, 1951; Grau 2010	0	0	0	0	?	2	2	1	2	0	1	1	1	1	1	1	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	0	1	0	0
Geoplana boraceia a	Almeida et al. 2018	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	1	2	0	0	0	0	0	0	1	0
"Geoplana" quagga b	Marcus 1951; F1736; F7848	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	0	1	1	0	0
Gigantea sp. a	F7514	1	0	0	0	1	0	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	1	0	1	2	0	0	2	0	0	0	1	1	1	0	1	0
Gusana sp. 2	F4421	1	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	0	1	2	0	0	2	0	0	0	0	0	0	1	0	1
Gusana sp. 3	F4428	1	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	0	1	2	0	0	2	0	0	0	0	0	1	1	0	1
Gusana sp. 1	Grau & Carbayo, unpublished	1	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	0	0	1	1	1	1	0	1	2	0	?	2	0	0	0	0	0	1	1	0	0
Imbira guaiana a	Carbayo 2003; Leal-Zanchet & Carbayo, 2001	0	0	0	0	1	0	1	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0
Imbira sp. 1	F5043; F5115; F5117	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	2	0
Imbira sp. 3	F5427; F54360	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	2	0
Imbira sp. 2	Carbayo 2003; Marcus 1951	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	2	0
Imbira sp. 4	Marcolino 2019; F2870; F3716; F3717	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	0	1	2	0
Issoca jandaia sensu Carbayo et al., 2013	F2043	0	1	0	0	1	0	1	0	1	0	1	1	0	1	1	0	2	1	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	1	1	0	2
Issoca rezendei a	Carbayo & Leal-Zanchet 2003; picture of an uncoded specimen; Grau2010;	0	1	0	0	1	0	1	0	1	0	1	1	0	?	1	0	2	1	0	0	1	1	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0

Luteostriata abundans a	Froehlich 1955 Carbayo 2003, 2010; Leal-Zanchet & Froehlich, 2006	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	0	2	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1
Luteostriata ernesti	Carbayo 2003, 2010; Leal-Zanchet & Froehlich, 2006	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	0	2	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1
Luteostriata muelleri	Carbayo 2003, 2010; Leal-Zanchet & Froehlich, 2006	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	0	2	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1
Matuxia matuta a	Carbayo 2003	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	0	0	2	0
Matuxia sp.	F1274	0	0	0	0	1	0	1	0	?	0	1	1	1	1	1	1	0	0	0	0	0	1	?	1	0	0	?	0	1	0	1	0	1	0	0	0	1
Matuxia tuxaua a	Carbayo 2003	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	1	1	0	1	1
Notogynaphallia plumbea	Carbayo 2003	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	2	0	0	1	1	0	1	0	0	1	1	0	1
Notogynaphallia sexstriata 2	Carbayo 2003	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	2	0	0	0	0	1	0	1	2	0	0	1	1	0	1	0	0	1	1	0	1
Obama ladislavii	Álvarez-Presas et al. 2015	1	0	0	0	1	1	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0
Obama nungara b	Carbayo et al. 2016	1	0	0	0	1	1	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	1	1	0	0
Paraba franciscana a	Leal-Zanchet & Carbayo 2001; F3475	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	2	?	0	0	0	0	0	0	0	0	1	2	0
Paraba multicolor a	Leal-Zanchet & Matos, 2011; F2141	1	0	0	0	1	?	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	0	0	2	0
Pasipha pasipha a	Marcus, 1951; Grau, 2010	0	0	0	0	1	1	1	0	1	?	1	1	1	1	1	1	0	0	0	0	0	0	1	0	?	0	0	?	2	0	1	0	0	1	1	1	0	0
Pasipha pinima	Froehlich, 1955; holotype; F1714	0	0	0	0	1	?	1	0	1	?	?	?	1	?	1	1	0	0	0	0	0	0	1	0	1	2	0	?	2	0	1	0	0	0	1	1	1	0
Pasipha tapetilla a	Marcus, 1951; F3202	0	0	0	0	1	0	1	0	1	?	?	?	1	1	?	?	?	?	0	0	?	1	0	1	0	0	?	2	0	1	0	0	0	1	1	0	1
Supramontana irritata a	Carbayo & Leal_Zanchet, 2003; F0191	0	0	0	0	1	?	1	0	1	0	1	1	0	1	1	0	2	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Xerapoa hystrix	Froehlich, 1955; Grau, 2010	0	0	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	1	0	1	2	0	1	2	0	0	0	0	0	0	0	0	0
Xerapoa pseudorhynchodemus	F1013	0	0	0	0	1	0	0	1	1	0	?	1	1	1	1	1	1	?	?	0	0	0	1	0	1	0	0	1	2	1	0	0	0	1	0	0	0	0

Supp. Mat. 1. Morphological matrix used for the ML analysis.

```
#NEXUS
[TITLE: MatrixMorphoDomingo]
begin data;
    dimensions ntax=47 nchar=37;
    format datatype=standard symbols="0123" missing=? gap=-;
matrix

Anzoplana 10001010001111????0000013002110000000
Endeavouri 00000011001111110000000120021100011101
F0205 00001010101101102000110101000000001101
F0327 00001010101101102000110101000000000101
F0358 0000?22120111111000001102000000000100
F0365 00111011011101011010110120011110011101
F0395 10001010000111110011110120?2000001100
F0432 00001011001111110000001000000000011120
F0792 00001010001111112000010120011010011101
F1013 00010011 0?111111??0001010012100010000
F1034 00011011011110011000010100011110101 01
F1182 01001010101 10?1021001101000110001 0000
F1244 10001010 0?1110??00000101?0?1100000000
F1274 00001010?011111100000 1?100?0101010001
F1275 00001010001111110000010100001010 11011
F1418 10001110101110110000010120000000 10000
F1714 00001?101???1?1100000101 20?2010001110
F1736 00001010001111110000010120010000011 00
F1841 00001110 1?111111000001 0?00?2010011100
F2031 10001010001110110000010100010000 11012
F2043 01001010101101102100110100000010001102
F2101 10001?10101110110000010120000000 10020
F2184 00001010001111110000010100000101010020
F2724 10001010101111110000010120010000000000
```

F2807 1000101010111011000001012001000001000
F2833 0000101000111111000000001000000010120
F2870 0000101000111111000000010011000010120
F2878 000010101???11????00?10100?2010001101
F3057 0001001101111111000001012012000000000
F3072 0000101000111111000001012001101001101
F3092 0011101101110101101111012001111010110
F3247 1000111010111011000001012000000011100
F3315 0011101101110101101011012001111001101
F3357 0000101010111111000001002?00000000120
F3358 0000101010110110200011010100000001101
F3387 0001101101111001100001010001111010101
F3453 00001?10101101102010110100000000000000
F3494 0011101101110101101011012000100001010
F3931 00001010???????????0?00?0??1100010001
F4217 0011101101110101101011012001111000100
F4358 0000101010111111000000011001200000010
F4421 1000101000111111001111012002000000101
F4428 1000101000111111001111012002000001101
F5043 0000101000111111000000000001000010120
F5427 0000101000111111000000000001000010120
F5512 1000101000111011000001012001000011102
F7514 1000101010111011000001012002000111010
;

end;

Chapter 4

Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest

This is the accepted version of the following article: **Lago-Barcia D**, DaSilva MB, Conti LA, Carbayo F (2020) Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest. PLOS ONE 15(7): e0235949. https://doi.org/10.1371/journal.pone.0235949

Abstract

Areas of endemism (AoE) are the main study units in analytical biogeographic methods, and are often defined as an area with two or more endemic species living in them, presenting substantial congruence among their range limits. We explored the distribution of land planarians (Geoplanidae, Platyhelminthes) across the southern region of the Brazilian Atlantic forest (from the state of Rio de Janeiro, to the state of Rio Grande do Sul) utilizing DaSilva's *et al.* (2015) protocol. We used two methods, Endemicity Analysis (EA), and Geographical Interpolation of Endemism (GIE). We identified nine AoE of terrestrial flatworms in the Southern Atlantic forest. Performance of the methodologies is discussed. These AoE of land planarians can be explained through vicariance events combined with their physiological and ecological own limitations. Interestingly, these AoE are congruent with fine-scale approaches such as that with harvestmen. Most land planarians have revealed to present a very small distributional range evidencing their potential as a good model for fine-scale studies of AoE.

Keywords: Geoplaninae, terrestrial flatworms, Brazil, rain forest, NDM, EA, GIE, kernel interpolation, biogeography.

Introduction

Historical biogeography has evolved substantially since its beginning three centuries ago [1]. One of its main objectives is to detect areas of endemism (AoE) [2]. Because AoE are the main study units in analytical biogeographic methods [3, 4], they can serve to design biogeographic regionalization schemes [5], to infer historical relationships between them [6], to study organism-climate dynamics [7], and as a criterion to identify areas for conservation [8, 9, 10, 11]. Different methodologies have been proposed to achieve said objectives [12-21] with different animal taxons [3, 22-26].

AoE are hypothesized areas that can vary depending on the data use [13, 27, 40-42]. AoE are often defined as an area with two or more endemic species living in them, presenting substantial congruence among their range limits [27]. Those basic criteria are based on the concept of a common biogeographical origin and/or isolation of those species ranges [3, 28].

The Atlantic Forest is one of the largest forests in the Americas, extending over approximately 150 million hectares [29]. Longitudinal, latitudinal and altitudinal ranges have modeled different climatic and environmental conditions producing distinct environments in it [30, 31]. These different conditions have created a complex biome that is characterized by high levels of endemism (averaging nearly 50% overall, and as high as 95% in some groups; [32]).

Since the proposition of the first biogeographic regionalization of the world, by Wallace [33], many studies identifying AoE have been carried out, including those in the Atlantic Forest in the 20th century (Fig. 1). Through the years, the AoE proposed for the Atlantic Forest vary in size and number depending on the taxonomic group being studied. Müller [22] divided the Atlantic Forest into 3 AoE using amphibians, reptiles, birds and mammals. He named them Pernambuco, Bahia and Paulista. The author considered AoE as those areas where endemic species distributions overlapped. Kinzey [23] identified the same AoE as Müller, though smaller in size, using primate distributions. Cracraft [3] suggested two AoE using bird distributions; one of these areas extends from Pernambuco to Santa Catarina, and the other covers the so called "Paranaense Forest", as named by Morrone [28]. Amorim & Pires [34] detected two large AoE, using diptera and primate distributions. These two large areas are located in

the borderline between Espírito Santo and Rio de Janeiro states and were subdivided into smaller areas, namely the northern area, in turn with four subareas, and the southern area, with two. Costa *et al*., [35] also discovered two large AoE using mammals distribution. Differently from Amorim & Pires [34] and Müller [22], they positioned the limit between these two areas 300 km further south, though, concordant with Müller [22], the northern area was subdivided into the same four subareas. Silva & Casteleti [24] detected five AoE of butterflies, birds and primates. Those areas were named Brejos Nordestinos, Pernambuco, Diamantina, Bahia and Serra do Mar. Brejos Nordestinos are higher altitude forest spots, surrounded by Caatinga in the states of Ceara, Pernambuco, Paraiba, and Piaui states; Pernambuco is situated in the coastal region of occidental Northeast Brazil; Diamantina is located in the interior of the state of Bahia; Bahia extends from the state of Sergipe to the state of Espirito Santo; Serra do Mar comprises the mountainous areas from Rio de Janeiro to Rio Grande do Sul states. The five AoE of Silva & Castelei [24] were delimited adjacent to three mixed transitional areas named São Francisco, Florestas do Interior and Florestas de Araucária. Silva *et al*. [36] proposed four AoE using bird ranges: Pernambuco (as defined in previous studies); Bahia Central (corresponding to Diamantina in Silva & Casteleti [24]); Bahia (homonym of Bahia AoE in Silva & Casteleti [24]); and Serra do Mar, the latter located on both sides of the Rio Doce, and extending from Espírito Santo to the northern Santa Catarina. Prado *et al*. [26] detected a single AoE of rodents in the Atlantic Forest region, the so-called Eastern South America, and subdivided it into four subregions. Each subregion would coincide with Pernambuco, Bahia, Diamantina and Serra do Mar AoE of Silva & Casteleti [24], respectively. Pinto-da-Rocha *et al*. [37], DaSilva & Pinto-da-Rocha [38] and DaSilva *et al*. [25] detected 12 AoE using harvestmen distributions. Only two out of the 12 were coincident with previously proposed AoE, namely Pernambuco and Bahia. The remaining ten AoE are small areas placed within AoE mentioned in the literature. Hoffmeister *et al.* [19] detected 29 groups of AoE. Some of these groups were congruent with previously delimited areas discovered by different authors. Based on orchid bee distributions, Garrafoni *et al.* [39] found at least five main AoE, which are congruent with those from Silva & Casteleti [24], varying only in size.

Refinement of the methods in the discovery of AoE has accordingly produced more refined, congruent areas inferred from different taxonomic groups. General differences are related to size and shape of the areas.

Numbers of AoE have varied according to progressive refinement of the methods and the taxonomic group used as model, either animals or plants. It is expected that lineages coexisting in a geographical space will also share overlapped biogeographic history. Deviations from this situation may be assigned to contingencies and to the unique ecological and physiological constraints undergone by each lineage. By contributing with additional taxa, new distributional data and new historical reconstructions of unexplored taxonomic groups, progress can be achieved in AoE knowledge [28] and new AoE hypotheses can be generated. Terrestrial flatworms or land planarians (Platyhelminthes, Geoplanidae) are one of those unexplored taxonomic groups. No biogeographic studies have been previously done using these animals. Terrestrial flatworms are very sensitive to changes in the conditions of their environment [43], are highly endemic due to their low vagility and dependence on humidity [44, 45] and are endemic to relatively small areas [46]. Furthermore, recent taxonomic revisions revealed that land planarians have smaller distributions than what was previously thought, due to the discovery of cryptic species under the same name [47-49]. For these reasons, land planarians are considered an optimal taxonomic group to carry out biogeographic studies. This paper aims to contribute to the debate of discovery and test of congruence of areas of endemism in the Atlantic forest. For this purpose, we explored the distribution of land planarians across the Atlantic Forest using two methods, Endemicity Analysis (EA), and Geographical Interpolation of Endemism (GIE).

Materials and methods

List of Abbreviations

AoE: Area of endemism

CC: Congruence Core

EA: Endemicity Analysis

GIE: Geographic Interpolation of Endemism

MIS: Area of endemism of Misiones

MRE: Maximum Region of Endemism
NDM/VNDM: Software that carries out an Endemicity Analysis
NSC: Area of endemism of North Santa Catarina
ORG: Area of endemism of the Serra dos Órgãos
POA: Area of endemism of Porto Alegre
PR: Area of endemism of Paraná
SFP: Area of endemism of São Francisco de Paula
SMSP: Area of endemism of Serra do Mar de São Paulo
SSC: Area of endemism of South Santa Catarina
SSP: Area of endemism of Southern São Paula
WS: Widespread

The study area comprises the areas covered with Atlantic forest between, and including, the state of Espírito Santo (the northernmost) and Rio Grande do Sul (the southernmost). We compiled distributional data belonging to 270 species of geoplanids (Tab. 1; S1 Table). For these species, 403 records were obtained from the literature and 166 from our own data, summing up a total of 570 records in our dataset (S1 Table). Species with doubtful records or identification, from literature or our own data, were not considered (S2. Table). One record is here understood as an observation of a species (either from literature or from our own data) in a certain locality, independently from the number of times this species was found.

For our own data, we intensely sampled land planarians in six areas (Fig. 2) (Parque Estadual de Intervales, Parque Nacional de Saint-Hilaire/Lange, Parque Nacional da Serra do Itajaí, Parque Estadual da Serra do Tabuleiro, Parque Nacional de São Joaquim and Floresta Nacional de São Francisco de Paula; ~200 person-hour of sampling). Other localities were sampled sporadically between 2009 and 2018. Each of these intensely sampled areas is at a distance of ~120 km in a straight line from the next one. As a result, we collected 1621 specimens. These specimens were diagnosed by either only their external aspect (for known and characteristic species regarding size, shape and color of the body) or through external aspect and morphological details of the cephalic region, the pharynx and the copulatory apparatus examined on histological glass slides produced following Carbayo & Almeida [50] (S1 Table). 156 out of the 1621 specimens could not be identified either because of their poor state of conservation

or due to their immature developmental status and were not further considered in this study. The remaining 1465 specimens belong to 94 known and 98 undescribed species, totalizing 192 species (S1 Table). We used GPS device Garmin E-Trex for recording the geographic coordinates with a maximum error of ~50 m of most of the specimens we collected. We used Googlemaps for recovering geographic coordinates of locations mentioned in the literature and a few of our own specimens which could not be georeferenced.

To discover AoE, the dataset was analyzed using two methods: (i) the Endemicity Analysis (EA), which uses a heuristic algorithm of the software NDM/VNDM (version 3.1, developed by Goloboff [51], Szumik *et al.* [14] and complemented by Szumik & Goloboff [15]), and (ii) the Geographical Interpolation of Endemism (GIE) based on a Kernel interpolation [18]. Resulted patterns were evaluated by combined criteria by DaSilva *et al.* [25], whose protocol was applied for a final delimitation.

The first approach (i), EA, is based on an optimality criterion which uses species distributions to identify AoE. It uses an heuristic algorithm to calculate an endemicity score for each set of cells containing endemic species on a grid on a map. The criteria used in this method were: (a) an area consisting of two or more grid cells presenting two or more endemic species (any species whose range is restricted to these or adjacent grid cells; see below), and (b) an endemicity score above two in each grid cell. We adjusted the points of grid origin to the default position provided by NDM and to three other origins randomly selected to test for eventual hidden AoE caused by its position, and subsequently run 100 replicas with each of five different grid cell sizes (0.1º, 0.25º, 0.3º, 0.5º, and 1º) to examine the effect of cell size on inferred patterns of endemism. We largely follow the protocol proposed by DaSilva *et al.,* [25] for several reasons discussed further below (see section *Discussion: 1. Methodological observations*). We computed consensus areas of endemism beginning, with 0.1º grid size cells, through a strict consensus or tight consensus rule [52, 53] using 5% similarity in species distribution between different sets of cells. Afterwards, we added the results obtained from analysis run with progressively larger grid cells (0.25º, 0.3º, 0.5º, and 1º) – sets resulting from larger grid cells are either the same as the smaller ones (but with coarser limits), the sums of two or more smaller ones or new areas [25]. Our complete dataset presents a number of gaps between sampled areas (Ex. S1-S8 Figure). Some of these

gaps represent unsampled areas (empty cells in NDM/VNDM, S1-S8 Figure) and others represent real absences of certain species (brown cells in NDM/VNDM, S1-S8 Figure).

The second approach (ii), GIE, is based on a kernel interpolation of the species distribution, indicating level of endemism based on the area of influence of the species and their distribution overlap [18]. The spatial modeling was performed with the GIE toolbox provided by [18] in Esri ArcGis software 10.6 (http://www.esri.com). The interpolation is based on the definition of areas of influence around species centroid points. These centroid points are calculated as arithmetic means of each species sampling coordinates [54]. Five categories of influence were determined based on the maximum distance between the centroid and the furthest point of occurrence for each species. Each category defines the radius of the area of influence around each species' centroid. The "influence" of each area decreases outwards, away from the centroid, according to a Gaussian function. The overlap between the areas of influence of all species was estimated by the kernel algorithm and the results were expressed in consensus normalized raster grids, representing relative levels of endemism. Although the establishment of the limits of classes and weight that can be given to each class is in certain way arbitrary, the representation of areas of endemism as natural units with fuzzy boundaries is more compatible with the theoretical models of distribution of AoE (see [13], [4]). In this study, we performed a variation of said arbitrary units (categorization schemes) to analyze the influence they may have on AoE identification through GIE. The first analysis was obtained by analyzing the normalized data (i.e. each of the five categories in the analysis had the same influence). The second analysis was done using five categories, with the predefined weight given by the GIE tool set [18]. In this analysis, species with smaller ranges weighted more (single record species not included in the consensus), progressively and exponentially losing weight in the successive categories. Species with a single record, and therefore present in a single locality, were named as 'Single Record'.

Species ranges that delimit or influence AoE in the numerical analyses (i. e., EA and GIE) were used to delimit the Congruence Cores (CC, [25]) of AoE. A CC is an endemic area by definition, but does not define an AoE by itself. Apart from species exclusively present within a CC, there may also occur species that do not contribute to the identification of a CC in the analyses. These species occur either in more than one CC, thus are defined and classified as widespread (WS) (i.e. a WS species is a species

found in at least two different CCs), or in one CC and outside of it, but never within the limits of another CC. The latter situation is the basis for delimiting a 'Maximum Region of Endemism' (MRE) [25]. Therefore a MRE is an expansion of the AoE using the distribution of species which are found inside its CC but never inside another CC. Finally, all species included in the study were classified within one of the four levels of endemicity (CC, MRE, WS, and Single Record species, modified from [25]). AoE are thus delimited with a CC and a MRE, when applied in addition to the delimitations directly achieved by the numerical methods (EA and GIE).

Ethics statement

Field permit number: ICMBio 57798-1, ICMBio 11748-4 (Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio)); EBBAut.020/2013 (Museu de Zoologia da Universidade de São Paulo (MZUSP)); 42.520/2007 (Instituto do Meio Ambiente de Santa Catarina (IMA) (former FATMA)).

Results

Endemicity Analysis with NDM/VNDM - method (i)

Best adjustment of the points of grid origin were to -56.0 (X), -19.1 (Y). The analysis employing the 0.1º cell size grid, produced four sets of preliminary AoE. The consensus analysis of these sets generated the following three consensus-sets. The northernmost consensus set, named North Santa Catarina (Table 1; S1 Figure) is located in the north-east region of the state of Santa Catarina (Fig. 3). It is defined by two species (to see species list see Supplementary Figures S1-S8) (latter defined using 0.25º-cells as well). Consensus-set of South Santa Catarina (S2 Figure) is located in the south-east region of the state of Santa Catarina (Fig. 3); it is defined by two species (three species define with 0.25º-cells as well). The southernmost consensus-set identified is the São Francisco de Paula (S3 Figure), located in the Floresta Nacional de São Francisco de Paula, in the state of Rio Grande do Sul (Fig. 3). It is defined by five species.

The analysis employing 0.25º cell size grid generated nine sets, and the consensus analysis generated six sets, namely the above-mentioned three sets using 0.1º-cells (obviously differing in the size, but defined by the same species each, respectively) plus two new sets. One of these new sets is the consensus-set of the Serra dos Órgãos (S4

Figure), located in the Serra dos Órgãos, in the state of Rio de Janeiro (Fig. 3). This set is defined by two species (the latter species define with 0.5°-cells as well). The other consensus-set is the Serra do Mar de São Paulo (S5 Figure), located in the state of São Paulo (Fig. 3). This set is defined by three species. The remaining sets produced would be a disjunct AoE, which overlaps with other sets previously generated (South Santa Catarina and São Francisco de Paula) (S6 Figure) and therefore presents WS species; thus, it cannot be considered an AoE.

Analysis run using 0.3º cell size grids generated sets of preliminary AoE all overlapping with sets generated with smaller cell size grids. These results are not shown.

The analysis employing 0.5º cell size grid generated 19 sets, and the consensus analysis generated five sets four of which overlap sets previously generated by the other sized grid analyses plus only one new, named Porto Alegre (S7 Figure). This consensus-set is located in the metropolitan area of Porto Alegre, in the state of Rio Grande do Sul (Fig. 3), and is defined by three species

The last analysis was run with 1º cell size grid. It generated thirty three sets from which the consensus analysis resulted in five sets. Four of these sets overlap existing sets previously generated and one set is new. This new consensus-set is named Misiones (S8 Figure) and is located in the province of Misiones, Argentina (Fig. 3). This set is defined by two species.

In short, the seven AoE identified through EA, named after the geographical location of their consensus-sets, are as follows: Serra dos Órgãos, Serra do Mar de São Paulo, North Santa Catarina, South Santa Catarina, São Francisco de Paula, Porto Alegre and Misiones.

Geographical Interpolation of Endemism - method (ii)

Final products of this method are expressed in density surface grids. As expected, the first analysis (with normalized categories) generated an AoE as large as our sampling area housing less inclusive minor AoE (Fig. 4).

The second analysis (with five categories, default weights and species with Single Record species excluded) (Fig. 5) showed major congruence with the results obtained through EA. This second analysis produced seven areas. In this analysis, species with

smallest ranges weighted more (single record species not included in the consensus), progressively and exponentially losing weight in the successive categories.

We therefore identify seven areas through GIE analysis. The northernmost area, named Serra dos Órgãos, is located in the Serra dos Órgãos, in the state of Rio de Janeiro. This area is defined by some undetermined level of influence from 30 species (Tab. 1). Moving south, the next area identified is Serra do Mar de São Paulo. It is located in the southeastern region of the state of São Paulo, and is defined by some level of influence from 28 species (Tab. 1). The next area identified by GIE analysis is Southern São Paulo, located further south in the state of São Paulo. It is influenced by 19 species (Tab. 1). The fourth area is Paraná, located around Curitiba municipality, in the state of Paraná. This area is influenced by 13 species (Tab. 1). Continuing south, the area of Santa Catarina is found occupying most of the eastern region of the state of Santa Catarina. This area is influenced by 77 species (Tab. 1). The area of São Francisco de Paula and Porto Alegre, occupies a considerable region that extends from almost the southernmost region of the state of Santa Catarina to Porto Alegre's metropolitan area. It is defined by some influence of 34 species (Tab. 1). The last area identified is Misiones. Located in the province of Misiones in Argentina, this area is defined by some level of influence from six species (Tab. 1).

GIE does not indicate objectively the endemic species supporting an AoE [59], as a high number of them influenced in each spot of the map (see above).

Summing up, the seven AoE defined through GIE analysis are Serra dos Órgãos, Serra do Mar de São Paulo, Southern São Paulo, Paraná, Santa Catarina, São Francisco de Paula and metropolitan area of Porto Alegre, and Misiones. They were named based on their geographical location (Fig. 5).

Summarized Results (Fig. 6)

EA identified seven AoE (Serra dos Órgãos, Serra do Mar de São Paulo, North Santa Catarina, South Santa Catarina, São Francisco de Paula, Porto Alegre and Misiones) (Fig. 3). GIE identified seven AoE (Serra dos Órgãos, Serra do Mar de São Paulo, Southern São Paulo, Paraná, Santa Catarina, São Francisco de Paula and Porto Alegre and Misiones) (Fig. 5). These areas can be summarized in nine AoE of terrestrial flatworms in the Southern Atlantic forest. Three of them are found by both, EA and GIE. Another four areas found by EA are also found by GIE, but in GIE they are

merged into two AoE (the sums of North Santa Catarina + South Santa Catarina and Porto Alegre + Misiones). The last two AoE were found only by GIE (Paraná and Southern São Paulo).

CCs of these areas were delimited by the ranges of species that contributed to the score of EA sets, drawing a line around those species ranges (Fig. 6. S3 Table). The CCs of the two AoE found only by GIE (Paraná and Southern São Paulo) were delimited by the single localities where endemic species have congruence (in both cases, only one species have more than one record) (Fig. 6).

Eleven species do not occur in any CC so they are not classified within any of the levels of endemicity (CC, MRE, WS).

The results of both numerical analyses were summarized on a map of AoE with CCs and MREs (Fig. 7). ORG was found by EA and GIE and has a CC defined by two species (those that score in EA). *Geoplana notophthalma* Riester, 1938 occurs in this CC but has a record in Minas Gerais state which consequently defines a MRE of ORG. SMSP was found by EA and GIE and has a CC defined by three species (those that score in EA with 0.25º and 0.3º cells). Five species occur in the CC and widens it to a MRE (*Choeradoplana marthae, Choeradoplana banga, Obama braunsi*, *Obama evelinae, Obama schubarti*). Those five species delimited a set in EA with 0.5º cells, but actually do not have congruent ranges. This result is caused by an artifact of cell size and position for the large size of them compared to the species ranges pattern, so we decided to consider them as delimiting a MRE. PR and SSP were found only by GIE and are defined by a CC with a single locality each. SSP widens to MRE as defined by *Issoca potyra* Froehlich, 1958 and *Paraba tapira* (Froehlich, 1958) and PR widens to a MRE defined by *Notogynaphallia mourei* (Froehlich, 1956).

Discussion

1. Methodological observations

As seen in previous studies, cell size and grid origin have impacts on the results obtained from an EA analysis. Large-sized cell grids generate less detailed hypotheses of species composition and area coverage of the AoE [14, 55, 56], generating a higher number of AoE, as can be seen in the present study. Usage of large-sized cell grids affects results, such as the collapse of two AoE into a single one [25] or the inclusion of

important barriers within a single AoE [57]. On the other hand, small grids introduce false absence of species, make distributions discontinuous, and present smaller number of species per cell, making it more difficult to detect AoE and, therefore, defining fewer of them [57]. Influences derived from cell size in revealing AoE are alleviated by DaSilva's *et al.* [25] protocol. It is important to use different grid cell sizes in EA or Parsimony Analysis of Endemicity – if only one cell size grid had been used or tested with our data, some AoE would have been missed through EA.

On the other hand, GIE analysis includes another "scaling effect" similar to the cell size grid dilemma mentioned before. There are two arbitrarily chosen units in GIE analysis. One unit is the number of categories of influence to be used in the analysis. The other is the values limiting the influence of each category (the relative weight each class will have in the analysis). Tests varying the number of categories have shown that modifying this unit, will not affect significantly the results obtained via GIE analysis [18]. Although a large number of categories will definitely affect the analysis, identifying AoE with higher discontinuity and also showing "micro areas" which sometimes are composed by a single species. This overestimates the amount of detected AoE (following Platnick's [27] definition of an AoE, a single endemic species should not be able to define AoE) (S8 Figure). Therefore the chosen categorization scheme should be tested and evaluated for every dataset analyzed in order to evade defining highly discontinuous AoE or overidentifying the number of AoE.

With the dataset analyzed with normalized weighted categories (all weights are the same for every category) (Fig. 4), the obtained result is a single AoE comprising the whole study area with minor areas defined inside. This analysis is unable to identify AoE (AoE identified in this study by other GIE categorization schemes and EA) such as ORG, POA or MIS. The reason for this is the fact that the influence value of species with very restricted distributions is the same as the influence value of WS species. When trying to identify AoE, species with restricted ranges are much more indicative than WS species. Therefore, GIE analysis should be carried out with weighted categories.

The categorization scheme chosen for GIE in this study consisted of five weighted categories (default weights in the ArcGIS toolbox). Single Record species were not included in the consensus of this analysis to evade the identification of areas with one Single Record species and to try and minimize the effect of poorly sampled species on

AoE identification (see [58]). As EA does not take in account single-cell sets, which would be resulted from aggregation of many Single Record species, this analysis shows high congruence with EA results.

GIE analysis overcomes several problems generated from the use of grid cells [18]. It allows the use of distributional data with gaps and offers the possibility of identifying AoE with fuzzy edges which corresponds better with the spatial and temporary reality of AoE [4, 18]. In contrast, it does not show objectively the limits of an AoE, because of this fuzzy edges.

GIE fails to provide a set of species diagnosing the identified AoE [59] apart from the "scaling effect" derived from the arbitrary units chosen for the categorization scheme. The identification of an AoE should not be possible if the list of species diagnosing that area cannot be obtained. An approximate list of species influencing a specific AoE can be obtained with GIE, but those species cannot be classified as diagnostic species because numerically it is not possible to know the influence of each species in each AoE identified.

No method, neither EA or GIE, is able to perform a complete analysis to identify AoE, due to the different flaws each methodology presents [25, 57, 60]. The analysis perform differently, offering the possibility to detect AoE based on different methodological approaches. Therefore the most efficient way to work when trying to detect AoE is through the integration of different methodologies and parameters as seen in previous studies [18, 20, 25, 39]. By working with different numerical algorithms, functions and formulas and different theoretical and methodological approaches, we are able to analyze our databases with a broader spectrum and correlate our practical results to the reality of endemic species distribution and congregation, with a higher confidence.

DaSilva's protocol facilitates the integration of different methodologies when identifying AoE. The use of a Congruence Core (CC) to delimit the main area of endemic species congruence permits the inclusion of results obtained through other methodologies efficiently and avoids the artifacts caused by grid cells, fuzzy edges or others. Defining Maximum Region of Endemism (MRE) also sets the concept that an AoE does not occupy, only, the congruent space between endemic species, but the outside areas which might represent the dynamism of said endemic species as well [25, 61]. DaSilva's protocol also maximizes EA's performance by including several steps

that reduce the grid-size effect and by discarding a high number of resulted sets caused by several combinations of overlapping ranges and consequent redundancy between them. DaSilva's protocol is focused on grid-based methods, but can be an effective tool to integrate results obtained from other methodologies that obviate grids as well.

Species with a single record were included in this study, even though they are not considered in endemism analyses. In fact, EA only considers sets with two or more cells, thus a cell with many endemic species is not detected by the method as an AoE. GIE overcomes this problem, but is also unable to differentiate localities with just one species record from localities with two or more species records, as mentioned above. These limitations become evident in our study as we found eight additional localities to bear two or more endemic species recorded only once in the entire study area. From North to South, these localities are Santa Maria Madalena-RJ (two Single Record species), São José do Barreiro-SP (three Single Record species), Ubatuba-SP (four Single Record species), Matinhos-PR (four Single Record species), Três Barras-SC (two Single Record species), PN São Joaquim-SC (31 Single Record species), Derrubadas-SC (two Single Record species) and Santa Maria-RS (two Single Record species). We believe that these species represent important biological information for planarian distribution and diversity, and the methods should be reconsidered so the Single Record species compute for the discovery of AoE.

2. Inferring AoE based on land planarian distributions

Our dataset revealed nine AoE in total, plus eight localities with two or more Single Record species. Two AoE (SSP and PR) could not be detected by our EA. These AoE (SSP and PR) present an extremely high number of endemic species (19 and 18 species, respectively). These two AoE were not detected due to the fact that all except one species endemic to them are known from one locality and thus are not considered by EA, because the method only considers sets with two cells or more [25, 57].

As mentioned before, some species distributions do not completely overlap the CCs. Those species present in only one CC and outside of it will define a MRE. They can be interpreted as an extension from a CC due to ontological causes, or, as the source of an error such as undersampled regions. Most of the identified AoE do not have a MRE because planarian records are very concentrated in specific localities and regions, and those localities and regions were each delimited as an AoE (see discussion below).

Only four AoE delimited MREs: ORG, SMSP, SSP and PR. Some of the species defining MREs create doubtful AoE. Such is the case of *Geoplana notophthalma* which defines a distant portion of ORG's MRE northwards, in the state of Minas Gerais. This MRE is a peculiar configuration for an AoE as AoE are defined by the congruence of only species with small distributions [62]. WS species cannot define an AoE, but *G. notophthalma* cannot be considered a WS species as it is not found in any other AoE, apart from ORG. Thus, *G. notophthalma* is found in the geographic region of Serra dos Órgãos and in Minas Gerais, and must expand ORG's AoE's borders through a MRE, thus giving rise to a disjunct AoE. Froehlich [63] suggested this species to be synonym of *O. applanata* (Graff, 1899), but the situation would not change since their distribution is the same.

Each of the six intensively sampled areas is at a distance of 120 km from the nearest intensively sampled area and, interestingly, each one was revealed as an AoE. This situation rises a question: if we had sampled between these intensively sampled areas, would we have discovered additional AoE? In other words, geographic distribution of most land planarians might occur at a scale smaller than areas with 120 km in length. General assumptions of endemism have been proposed and explained as a consequence of the ecological and physiological limitations of these organisms [43, 46, 64]. If this is true, further sampling of these organisms is promising in revealing new AoE within the study area even so because most land planarians have revealed to present a very small distributional range and each of the six areas intensely sampled turned out to be an AoE.

3. Causal factors of areas of endemism

In general, Serra do Mar, the mountains spreading almost along the whole geographic range herein analyzed, is considered a single area of endemism for forest-dependent vertebrate and plant taxa [22, 24, 65, 66]. However, some studies have shown a more endemic pattern of distribution for species or populations in the southeastern-south coastal mountains and adjacent lowlands of Atlantic Forest, as seen with the area of endemism of harvestmen [25] and spiders [18], specific distributional congruence of vertebrates [67], ecological regionalization of frogs [68], and phylogeographic structure of species of frogs [69-72], bees [73], vipers [74], birds [75, 76], mammals [77, 78] and harvestmen [79, 80]. The main divergence is found to the south of the state of São Paulo

or close to Ribeira do Iguape river valley [6, 67, 71, 73, 74, 76], but with very different times of divergence between those taxa (~ 0.39–4.9 m.y.a.) and weak inference of causal processes.

The planarian species show very restricted ranges only compared to harvestmen species [25], or maybe to some frog or cricket taxa [81, 82]. They seem to be restricted to more humid portions of the forest on mountain slopes or adjacent regions, where the core of their areas of endemism is located, with few exceptions. Main valleys or sedimentary basins seem to be the barriers for those taxa, as described for Paraíba do Sul river and Ribeira do Iguape river [64, 67, 71, 73, 74, 76, 79, 80].

The Atlantic Forest is not physiognomically homogeneous. It presents humid forests concentrating on slopes or medium altitudes of mountains. The valleys and coastal plains are composed by a marine influenced vegetation, and interior lowlands of the south-southeastern region are composed by seasonal semideciduous forests. The endemic patterns found herein and for harvestmen show a restriction in more humid forests. This could be directly influenced by past events of forest reduction and posterior concentration in those regions, or refuges. A great body of literature from different sources and proxies continues to furnish evidence for reduction of forests in cycles during the Neogene (e.g. [70, 75, 83-85]). The high endemicity found for planarians seems to be influenced by those reductions, since PR x SC x SFP x POA and ORG x SMSP x SSP do not have clear geographic barriers. In this view, in the regions of those AoE cores, the forest should have been more humid than in lowland areas and consequently should have been maintained with few alterations during climatic fluctuations [25, 83, 86, 87].

The same should have happened to sedimentary basins wherein the great rivers flow. Those basins were originated by tectonism related with uprising of mountain ranges of Serra do Mar and Serra da Mantiqueira and subsidence of valleys since at least the Miocene [88-90]. In fact, the southeastern region of the Atlantic Forest is considered as the main rift system of eastern South America [89]. Some of those valleys started to be rain shadows as they are hidden from orographic rains and coastal humidity behind the Serra do Mar mountains (e.g. Paraíba do Sul river, [91]). Rivers originated as they flowed to the subsidence regions and most of their heads were captured from a western direction, eastward to the coast [92]. Sedimentation of those regions was affected by neotectonic reactivation [90] and rising of the amount of flowing water in

more humid periods, even forming paleolakes [89] or by marine transgressions into coastal valleys [93-95]. Then, many associated events feedbacked sedimentary basins as barriers for forest-dependent taxa, avoiding the development of humid forests for long periods. They resulted in many taxa splitting in these lowlands and valley regions but in different times between each other. DaSilva *et al.* [6] proposed a model of reiterative barriers with spatial congruence in multiple times to explain those patterns.

Álvarez-Presas *et al.* [64] have shown a phylogeographic structure for *Cephaloflexa bergi* planarian populations, congruent to those main barriers, Paraíba do Sul river and Ribeira do Iguape river valleys, and a split in northern São Paulo/south Rio de Janeiro states. There is not a clear geographic barrier associated to the latter, but is congruent to ORG X SMSP AoE, cited above, the same for harvestmen AoE [25], and phylogeographic structure for *Promitobates* harvestmen [79]. The dating estimates for those main splits of *Cephaloflexa* planarian is about 8 m.y.a., in the Miocene period, near to the *Promitobates* harvestmen splits estimated in about 11 m.y.a. It is important to note that possible reductions of forest caused by climatic desiccation probably occurred previously to the renowned and more recorded Pliocene/Pleistocene fluctuations [96-98]. In spite of lack of phylogeographic structure of some populations of *Cephaloflexa*, Álvarez-Presas et al. [64] assumed that populations remained separated by those main barriers and there were few more recent dispersions.

POA and MIS areas have a different character related to their physical conditions. It is assumed that those forests have seasonal deciduous physiognomies [99] in contrast to the humid evergreen forests of the other areas of endemism. These endemisms could be associated to those species ecological requirements or isolation from the surrounding open vegetations. However, MIS seems to be related to a separation at Paraná river or its tributary valleys, since they flow on an important sedimentary basin, as discussed above.

Based on this discussion, the hypotheses for the causes of the presented endemic patterns, inferred as speciation processes between endemic species living in those areas of endemism, should be tested or deepened by a phylogenetic framework with temporal estimation of each cladogenesis. The corroboration of the phylogeographic structure and the main populational divergence shown by Álvarez-Presas *et al.* [64] and the areas of endemism of hundreds of planarians species contribute to the understanding of the

biogeographical evolution of those animals and consequently, of the humid Atlantic Forest.

Conclusions

In this paper, we corroborate DaSilva's *et al.,* (2015) protocol as an effective tool to aid in the discovery of AoE. This protocol was used with two numerical methodologies, namely an EA (grid-based) and a GIE (centroid-based). The protocol exploits the advantages of each numerical methodology (EA allows the identification of species defining an AoE and permits a more accurate delimitation of an AoE; GIE even detects AoE consisting of a single record), whereas a number of potential AoE failed to be noticed by the numerical methods.

The AoE of land planarians discovered here are congruent with fine-scale approaches such as that addressed by DaSilva *et al.* (2015) for harvestmen. Land planarians and harvestmen are hygrophilous and forest-dependent organisms and present sensitivity to environmental changes. Presumably, due to these common physiological and ecological constraints, harvestmen and land planarians may predict, more robustly, a common history of other restricted taxa of the Atlantic Forest. Furthermore, new samplings in unexplored localities in the study area might indeed uncover new endemisms and additional AoE. Hence, these organisms might be a good model for fine-scale studies of AoE.

Acknowledgements

We thank Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Instituto Florestal do Governo do Estado de São Paulo (IF), Museu de Zoologia da Universidade de São Paulo (MZUSP), Fundação do Meio Ambiente do Governo Estado de Santa Catarina (FATMA) for sampling licence in Parque Nacional da Serra dos Órgãos, Parque Nacional Saint Hilaire/Lange, Parque Nacional da Serra de Itajaí, Floresta Nacional de São Francisco de Paula (ICMBio); Parque Estadual Intervales (IF), Parque Estadual da Serra do Tabuleiro (FATMA). We are indebted to Ana Laura Almeida, Claudia Tangerino Olivares, Júlio Pedroni, Débora Redivo, Karine Gobetti, Leonardo Zerbone, Marília Jucá, Marta Álvarez Presas, and Welton Araujo for

sampling help; Ítalo Silva de Oliveira Sousa, Geison Castro da Silveira, and Lucas Beltrami for the histological work; and K. Gobetti for the help with histological slides of E. M. Froehlich collection.

References

1. Morrone JJ, Crisci JV. Historical biogeography: introduction to methods. Annu. Rev. Ecol. Syst. 1995;26: 373–401.
2. Henderson IM. Biogeography without area? Austral Syst Bot. 1991;4: 59.
3. Cracraft J. Historical biogeography and patterns of differentiation within the South American avifauna: areas of endemism. Ornithol. Monogr. 1985;36: 49–84.
4. Crother BI, Murray CM. Ontology of areas of endemism. J Biogeogr. 2011;38(6): 1009-1015.
5. Morrone JJ. Biogeographical regionalisation of the Neotropical Region. Zootaxa. 2014;3782(1): 001–110.
6. DaSilva MB, Pinto-da-Rocha R, and Morrone JJ. Historical relationships of areas of endemism of the Brazilian Atlantic rain forest: a cladistic biogeographic analysis of harvestman taxa (Arachnida: Opiliones). Curr Zool. 2016;63(5): 525-535.
7. Gámez N, Nihei SS, Scheinvar E, Morrone JJ. A temporally dynamic approach for cladistic biogeography and the processes underlying the biogeographic patterns of North American deserts. J Zoolog Syst Evol Res. 2014. https://doi.org/10.1111/jzs.12142.
8. Vane-Wright RI, Humphries CJ, Williams PH. 1991. What to protect? Systematics and the agony of choice. Biol Conserv. 1991;55: 235–254. https://doi.org/10.1016/0006-3207(91)90030-d
9. Rodrigues AS, Orestes Cerdeira J, Gaston KJ. Flexibility, efficiency, and accountability: Adapting reserve selection algorithms to more complex conservation problems. Ecography. 2000;23: 565–574. https://doi.org/10.1111/j.1600-0587.2000.tb00175.x

10. Díaz Gómez JM. Estimating ancestral ranges: Testing methods with a clade of Neotropical lizards (Iguania: Liolaemidae). PloS One. 2011;6: e26412. https://doi.org/10.1371/journal.pone.0026412
11. Martínez-Hernández F, Mendoza-Fernández AJ, Pérez-García FJ, Martínez-Nieto MI, Garrido-Becerra JA, Salmerón-Sánchez E, Merlo ME, Gil C, Mota JF. (2015) Areas of endemism as a conservation criterion for Iberian gypsophilous flora: a multi-scale test using the NDM/VNDM program. Plant Biosyst. 2015;149(3): 483-493. https://doi.org/10.1080/11263504.2015.1040481
12. Rosen BR. From fossils to earth history: Applied historical biogeography. . In: Myers A, Giller P, editors. Analytical biogeography: An integrated approach to the study of animal and plant distribution. Chapman and Hall, London; 1988. p. 437-481.
13. Morrone JJ. On the identification of Areas of Endemism. Syst. Biol. 1994;43: 438–441.
14. Szumik C, Cuezzo F, Goloboff PA, Chalup A. An optimality criterion to determine areas of endemism. Syst Biol. 2002;51: 806–816.
15. Szumik C, Goloboff PA. Areas of endemism: an improved optimality criterion. Syst Biol. 2004;53: 968–977.
16. Porzecanski AL, Cracraft J. Cladistic analysis of distributions and endemism (CADE): Using raw distributions of birds to unravel the biogeography of the South American arid lands. J Biogeogr. 2005;32: 261–275. http://dx.doi.org/10.1111/j.1365-2699.2004.01138.x
17. Dos Santos DA, Fernández HR, Cuezzo MG, Domínguez E. Sympatry inference and network analysis in biogeography. Syst. Biol. 2008;57: 432–448.
18. Oliveira U, Brescovit AD, Santos AJ. Delimiting Areas of Endemism through Kernel Interpolation. PLoS ONE. 2015;10(1): e0116673.
19. Hoffmeister CH, Ferrari A. Areas of endemism of arthropods in the Atlantic Forest (Brazil): an approach based on a metaconsensus criterion using endemicity analysis. Biol J Linn Soc. 2016;119(1): 126–144. https://doi.org/10.1111/bij.12802
20. Morales-Guerrero A, Miranda TP, Marques AC. Comparison between Parsimony Analysis of Endemicity (PAE), Endemicity Analysis (EA), and an alternative coding of Three-Distribution Statements based on hypothetical

distributions. Syst Biodivers. 2017;15(5): 391-398. https://doy.org/10.1080/14772000.2016.1257519

21. Salinas NR, Wheeler WC. Statistical Modeling of Distribution Patterns: A Markov Random Field Implementation and Its Application on Areas of Endemism. Syst. Biol. 2019;0(0): 1–15. https://doi.org/10.1093/sysbio/syz033
22. Müller P. The dispersal centres of terrestrial vertebrates in the Neotropical realm: a study in the evolution of the Neotropical biota and its native landscape. Biogeographica 2. 1973; 1–250.
23. Kinzey WG. 1982. Distribution of primates and forest refuges. In: Prance GT, Editor. Biological diversification in the tropics. Columbia University Press, New York, New York; 1982. p. 455-482.
24. Silva JMC, Casteleti CHM. Estado da biodiversidade da Mata Atlântica brasileira. In: Galindo–Leal C, Câmara IG, editors. Mata Atlântica: Biodiversidade, Ameaças e Perspectivas. 2005.
25. DaSilva MB, Pinto-da-Rocha R, DeSouza AM. A protocol for the delimitation of areas of endemism and the historical regionalization of the Brazilian Atlantic Rain Forest using harvestmen distribution data. Cladistics. 2015;31: 692-705.
26. Prado JR, Brennand PGG, Godoy LP, Libardi GS, Edson, Abreu-Jr F, Roth PRO, Chiquito EA, Percequillo AR. Species richness and areas o endemism of oryzomyine rodents (Cricetidae, Sigmodontinae) in South America: an NDM/VNDM approach. J Biogeogr. 2015;42: 540–551.
27. Platnick NI. On areas of endemism. Aust. Syst. Bot. 1991;4: 11-12.
28. Morrone JJ. Homology, biogeography and areas of endemism. Divers. Distrib. 2001;7: 297–300.
29. Morellato LPC, Haddad CFB. Introduction: The Brazilian Atlantic Forest. Biotropica. 2000;32(4b): 786-792.
30. Leitão-Filho HF, Morellato LPC. Semideciduous forests of Southeastern Brasil – Serra do Japi. In: Davis SD, Heywood VH, Herrera-MacBryde O, Villa-Lobos J, Hamilton AC, editors. Centres for plant diversity: a guide and strategy for their conservation. IUCN, WWF, Washington; 1997. p. 381-384.
31. Câmara IG. Brief history of conservation in the Atlantic Forest. In: Galindo-Leal C, Câmara IG, editors. The Atlantic Forest of South America: Biodiversity

Status, Threats, and Outlook. CABS and Island Press, Washington; 2003. p. 31–42.

32. Brown K, Jil S, Brown GG. Habitat alteration and species loss in Brazilian forests. In: Whitmore TC, Sayer JA, editors. Tropical deforestation and species extinction. Chapman and Hall, London, England; 1992. p. 119-142.
33. Wallace AR. On the monkeys of the Amazon. Proc. Zool. Soc. Lond. 1852;20: 107– 110.
34. Amorim DS, Pires MRS. Neotropical biogeography and a method for a maximum biodiversity estimation. In: Bicudo CEM, Menezes NA, editors. Biodiversity in Brazil. A First Approach. Conselho Nacional de Desenvolvimento Cientifico e Tecnologico, São Paulo; 1996. p. 183-219.
35. Costa LP, Fonseca GAB, Fonseca MT. Biogeography of South America forest mammals: endemism and diversity in the Atlantic Forest. Biotropica. 2000;32: 872-881.
36. Silva JMC, Sousa MC, Castelletti CHM. Areas of endemism for passerine birds in the Atlantic forest, South America. Glob Ecol Biogeogr. 2004;13: 85-92.
37. Pinto-da-Rocha R, DaSilva MB, Bragagnolo C. Faunistic similarity and historical biogeography of the harvestmen of southern and southeastern Atlantic Rain Forest of Brazil. J. Arachnol. 2005;33: 290–299.
38. DaSilva MB, Pinto-da-Rocha R. A historia da Mata Atlantica atraves da distribuicão dos opiliões (Arachnida). In: Carvalho CJB, Almeida EAB, editors. Biogeografia da America do Sul: Padrões e Processos. Editora Roca, São Paulo; 2011. p. 221–238.
39. Garrafoni ARS, Moura FR, Lourenco AP. Areas of endemism in the Atlantic Forest: quantitative biogeography insights from orchid bees (Apidae: Euglossini). Apidologie. 2017;48: 513. https://doi.org/10.1007/s13592-017-0494-6
40. Espinosa D, Aguilar C, Escalante T. Endemismo, áreas de endemismo y regionalización biogeográfica. In: Llorente J, Morrone JJ, editors. Introducción a la biogeografía en Latinoamérica: teorías, conceptos, métodos y aplicaciones. México D.F: Las Prensas de Ciencias; 2001. p. 3137.
41. Linder P. On areas of endemism, with an example from the African Restionaceae. Syst. Biol. 2001;50: 892–912.

42. Carine MA, Humphries CJ, Guma IR, Reyes-Betancort JA, Guerra AS. Areas and algorithms: evaluating numerical approaches for the delimitation of areas of endemism in the Canary Islands archipelago. J Biogeogr. 2009;36: 593–611.
43. Carbayo F, Leal-Zanchet AM, Vieira EM. Terrestrial flatworm (Platyhelminthes: Tricladida: Terricola) diversity vs. man-induced disturbance in a subtropical rainforest from Southern Brazil. Biodivers Conserv. 2002;11: 1091-1104.
44. Sluys R. Platyhelminthes as paleogeographical indicators. Hydrobiologia. 1995;305: 49-53.
45. Winsor L, Johns PM, Yeates GW. Introduction, ecological and systematic background to the Terricola (Tricladida). Pedobiologia. 1998;42: 389-404.
46. Sluys R. Global diversity of land planarians (Platyhelminthes, Tricladida, Terricola): a new indicator-taxon in biodiversity and conservation studies. Biodivers Conserv. 1999;8: 1663–1681.
47. Lemos VS, Cauduro GP, Valiati VH, Leal-Zanchet AM. Phylogenetic relationships within the flatworm genus Choeradoplana Graff (Platyhelminthes : Tricladida) inferred from molecular data with the description of two new sympatric species from Araucaria moist forests. Invertebr Syst. 2014;28: 605–627. http://dx.doi.org/10.1071/IS14003
48. Almeida AL, Marques FPL, Carbayo F. 'Endless forms most beautiful': taxonomic revision of the planarian Geoplana vaginuloides (Darwin, 1844) and discovery of numerous congeners (Platyhelminthes: Tricladida). Zool J Linnean Soc. 2018;20: 1–65.
49. Lago-Barcia D, Carbayo F. Taxonomic revision of four species of the Neotropical land planarian genera Cratera and Geoplana (Platyhelminthes, Tricladida) with a description of two new species and an emendation of Cratera. Zootaxa. 2018;4500(4): 517–542
50. Carbayo F, Almeida AL. Anatomical deviation of male organs of land planarians from Rio de Janeiro, Brazil, with description of two new species of Cratera (Platyhelminthes, Tricladida). Zootaxa. 2015;3931(1): 027–040. http://dx.doi.org/10.11646/zootaxa.3931.1.2
51. Goloboff P. NDM and VNDM: Programs for the identification of areas of endemism, vers. 1.6. 2002.

52. Szumik C, Casagranda D, Roig-Junent S. Manual de NDM/VNDM: programas para la identificación de áreas de endemismo. Inst. Arg. Est. Filogenet. 2006;5(3):1–26.
53. Aagesen L, Szumik C, Goloboff P. Consensus in the search for areas of endemism. J Biogeogr. 2013;40: 2011–2016.
54. Franklin J. Mapping species distributions: spatial inference and prediction. Cambridge University Press. 2010.
55. Szumik C, Aagesen L, Casagranda D, Arzamendia V, Baldo D, Claps LE, Cuezzo F, Gomez JMD, Giacomo AD, Giraudo A, Goloboff P, Gramajo C, Kopuchian C, Kretzchmar S, Lizarralde M, Molina A, Mollerach M, Navarro F, Nomdedeu S, Panizza A, Pereyra VV, Sandoval M, Scrocchi G, Zuloaga FO. Detecting areas of endemism with a taxonomically diverse data set: plants, mammals, reptiles, amphibians, birds and insects from Argentina. Cladistics. 2012;1: 1–13.
56. Aagesen L, Szumik C, Zuloaga FO, Morrone O. Biogeography of the South America highlands—recognizing the Altoandina, Puna, and Prepuna through the study of Poaceae. Cladistics. 2009;25: 295–310.
57. Moline PM, Linder HP. Input data, analytical methods and biogeography of Elegia (Restionaceae). J. Biogeogr. 2006;33: 47– 62.
58. Casagranda MD, Goloboff PA. On stability measures and effects of data structure in the recognition of areas of endemism. Biol. J. Linn. Soc. 2019;20: 1–13.
59. Escalante T. A natural regionalization of the world based on primary biogeographic homology of terrestrial mammals. Biol. J. Linn. Soc. 2016;120(2): 349–362. https://doi.org/10.1111/bij.12898.
60. Nihei SS. Misconceptions about parsimony analysis of endemicity. J Biogeogr. 2006;33: 2099–2106.
61. Noguera-urbano EA. Areas of endemism: travelling through space and the unexplored dimension. Syst. Biol. 2016;14(2): 131-139. https://doy.org/10.1080/14772000.2015.1135196
62. Deo AJ, DeSalle R. Nested areas of endemism analysis. J. Biogeogr. 2006;33: 1511–1526.

63. Froehlich CG. (1956). Tricladida Terricola das regi~oes de Teresopolis e Ubatuba. Pap Avulsos Zool. 1956;12: 313–344.
64. Álvarez-Presas M, Sánchez-Gracia A, Carbayo F, Rozas J, Riutort M. Insights into the origin and distribution of biodiversity in the Brazilian Atlantic forest hot spot: a statistical phylogeographic study using a low-dispersal organism. Heredity. 2014;112: 656–665. https://doi.org/10.1038/hdy.2014.3
65. Prance GT. Forest refuges: evidence from woody angiosperms. In: Prance GT, editor. Biological Diversification in the Tropics. Columbia University Press, New York, NY; 1982. p. 137–158.
66. Soderstrom TR, Judziewicz EJ, Clark LG. Distribution patterns of Neotropical bamboos. In: Vanzolini PE, Heyer WR, editors. Proceedings of a Workshop on Neotropical Distribution Patterns. Academia Brasileira de Ciências, Rio de Janeiro; 1988. p. 121–157.
67. Silva SM, Moraes-Barros N, Ribas CC, Ferrand N, Morgante JS. Divide to conquer: a complex pattern of biodiversity depicted by vertebrate components in the Brazilian Atlantic Forest. Biol. J. Linn. Soc. 2012;107: 39–55.
68. Vasconcelos TS, Prado VHM, Silva FR, Haddad CFB. Biogeographic Distribution Patterns and Their Correlates in the Diverse Frog Fauna of the Atlantic Forest Hotspot. PLoS ONE. 2014;9(8): e104130.
69. Fitzpatrick SW, Brasileiro CA, Haddad CFB, Zamudio KR. Geographical variation in genetic structure of an Atlantic Coastal Forest frog reveals regional differences in habitat stability. Mol Ecol. 2009;18: 2877-2896.
70. Carnaval AC, Hickerson MJ, Haddad CFB, Rodrigues MT, Moritz C. Stability predicts genetic diversity in the Brazilian Atlantic Forest Hotspot. Science. 2009;323: 785-789.
71. Brunes TO, Sequeira F, Haddad CFB, Alexandrino J. Gene and species trees of a Neotropical group of treefrogs: genetic diversification in the Brazilian Atlantic Forest and the origin of a polyploid species. Mol. Phylogen. Evol. 2010;57: 1120-1133
72. Amaro RC, Rodrigues MT, Yonenaga-Yassuda Y, Carnaval AC. Demographic processes in the montane Atlantic rainforest: molecular and cytogenetic evidence from the endemic frog *Proceratophrys boiei*. Mol. Phylogenetics Evol. 2012;62: 880-888.

73. Batalha-Filho H, Waldschmidt AM, Campos LAO, Tavares MG, Fernandes-Salomão TM. Phylogeography and historical demography of the Neotropical stingless bee *elipona quadrifasciata* (Hymenoptera, Apidae): incongruence between morphology and mitochondrial DNA. Apidologie. 2010;41: 534-547.
74. Grazziotin FG, Monzel M, Echeverrigaray S, Bonatto SL. Phylogeography of the B*othrops jararaca* complex (Serpentes: Viperidae): past fragmentation and island colonization in the Brazilian Atlantic Forest. Mol Ecol. 2006;15: 3969-3982.
75. D'Horta FM, Cabanne GS, Meyer D, Miyaki CY. The genetic effects of Late Quaternary climatic changes over a tropical latitudinal gradient: diversification of an Atlantic Forest passerine. Mol Ecol. 2011;20: 1923-1935.
76. Cavarzere V, Silveira LF, Vasconcelos MF, Grantsau R, Straube FC. Taxonomy and biogeography of Stephanoxis Simon, 1897 (Aves: Trochilidae). Pap Avulsos Zool. 2014;54: 69-79.
77. Mustrangi MA, Patton JL. Phylogeography and systematics of the Slender Mouse Opossum Marmosops (Marsupialia: Didelphidae). University of California Publications in Zoology. 1997;130.
78. Martins FM, Templeton AR, Pavan ACO, Kohlbach BC, Morgante JS. 2009. Phylogeography of the common vampire bat (*Desmodus rotundus*): Marked population structure, Neotropical Pleistocene vicariance and incongruence between nuclear and mtDNA markers. BMC Evol. Biol. 2009;9: 294.
79. Bragagnolo C, Pinto-da-Rocha R, Antunes M, Clouse RM. Phylogenetics and phylogeography of a long-legged harvestman (Arachnida: Opiliones) in the Brazilian Atlantic Rain Forest reveals poor dispersal, low diversity, and extensive mitochondrial introgression. Invertebr Syst. 2015;29: 386–404.
80. Peres EA, DaSilva MB, Antunes Jr M, Pinto-Da-Rocha R. A short-range endemic species from south-eastern Atlantic Rain Forest shows deep signature of historical events: phylogeography of harvestmen *Acutisoma longipes* (Arachnida: Opiliones). Syst. Biol. 2017. https://doi.org/10.1080/14772000.2017.1361479
81. Heyer WR, Maxson LR. Relationships, zoogeography, and speciation mechanisms of frogs of the genus Cycloramphus (Amphibia, Leptodactylidae). Arquiv. Zool. 1983;30(5): 341-373.

82. Mello FAG. Sistemática, distribuição e diferenciação de grilos do gênero *Aracamby* Mello, 1992 nas matas costeiras do sudeste do Brasil e sistema insular adjacente: aspectos morfológicos, cromossômicos e comportamentais (Orthoptera: Grylloidea: Phalangopsidae). PhD thesis, Instituto de Biociências, Universidade de São Paulo, Brazil. 1994.
83. Haffer J. Biogeography of Neotropical birds. In: Whitmore TC, Prance GT, editors. Biogeography and Quaternary history in tropical America. Oxford: Clarendon Press; 1987. p. 105-150.
84. Ledru MP, Rousseau DD, Cruz Jr FW, Riccomini C, Karmann I, Martin, L. Paleoclimate changes during the last 100,000 yr from a record in the Brazilian Atlantic rainforest region and interhemispheric comparison. Quarten Res. 2005;64: 444-450.
85. Saia SEMG, Pessenda LCR, Gouveia SEM, Aravena R, Bendassolli JA. Last glacial maximum (LGM) vegetation changes in the Atlantic Forest, southeastern Brazil. Quatern. Int. 2008;184: 195-201.
86. Jackson JF. Differention in the genera Enyalius and Strobilurus (Iguanidae): implications for Pleistocene climatic changes in eastern Brazil. Arq Zool Est São Paulo. 1978;30: 1-79.
87. Carnaval AC, Waltari E, Rodrigues MT, Rosauer D, VanDerWal J, Damasceno R, Prates I, Strangas M, Spanos Z, Rivera D, Pie MR, Frirkowski CR, Bornschein MR, Ribeiro LF, Moritz C. Prediction of phylogeographic endemism in an environmentally complex biome. Proc R Soc B. 2014;281: 1-8.
88. Almeida FFM, Carneiro CDR. Origem e evolução da Serra do Mar. Rev Bras Geoc. 1998;28(2): 135-150.
89. Riccomini C, Santanna L, Ferrari A. Evolução geológica do Rift Continental do Sudeste do Brasil. In: Mantesso Neto V, In: Bartorelli A,, In: Carneiro C,, In: Brito Neves B, eds. Geologia do Continente Sul-Americano: Evolução da Obra de Fernando Flávio Marques de Almeida. São Paulo: Beca; 2004. p. 383–405.
90. Saadi A, Bezerra FHR, Costa RD, Igreja HLS, Franzinelli E. 2005. Neotectônica da plataforma brasileira. In: Souza CRG, Suguio K, Oliveira AMS, Oliveira PE, editors. Quaternário do Brasil. Associação Brasileira de Estudos do Quaternário/ Holos Editora, Ribeirão Preto; 2005. p. 211-234.

91. Behling H, Lichte M. Evidence of dry and cold climatic conditions at glacial times in tropical southeastern Brazil. Quat Res. 1997;48: 348–358
92. Ribeiro AC. Tectonic history and the biogeography of the freshwater fishes from the coastal drainages of eastern Brazil: an example of faunal evolution associated with a divergent continental margin. Neotrop. Ichthyol. 2006;4: 225–246.
93. Martin L, Suguio K, Flexro JM. As flutuações de nível do mar durante o Quaternário Superior e a evolução geológica de “deltas” brasileiros. Boletim IG-USP publicação especial. 1993;15: 1-186.
94. Suguio K, Angulo RJ, Carvalho AM, Corrêa ICS, Tomazelli LJ, Willwock JÁ, Vital H. Paleoníveis do mar e paleolinhas de costa. Quaternário do Brasil. In: Souza CRG, Suguio K, Oliveira MAS, Oliveira PE, editors. Quaternário do Brasil. Ribeirão Preto: Associação Brasileira de Estudos do Quaternário/Holos Editora; 2005. p. 114-129.
95. Rossetti DF, Góes AM. Marine influence in the Barreiras Formation, State of Alagoas, northeastern Brazil. An Acad Bras Ciênc. 2009;81: 741-755.
96. Cerling TE, Harris JM, MacFadden BJ, Leakey MG, Quadek J, Eisenmann V, Ehleringer JR. Global vegetation change through the Miocene/Pliocene boundary. Nature. 1997;389: 153-158.
97. Ravelo AC, Andreasen DH, Lyle M, Lyle AO, Wara MW. Regional climate shifts caused by gradual global cooling in the Pliocene epoch. Nature. 2004;429:263-267.
98. Holbourn A, Kuhnt W, Lyle M, Schneider L, Romero O, Andersen N. Middle Miocene climate cooling linked to intensification of eastern equatorial Pacific upwelling. Geology. 2014;42: 19-22.
99. IBGE 2012. Mapa da Área de Aplicação da Lei n° 11.428 de 2006 (1 : 5,000,000), 2nd edn. Rio de Janeiro: Fundação Instituto de Geografia e Estatística (IBGE).

Figures

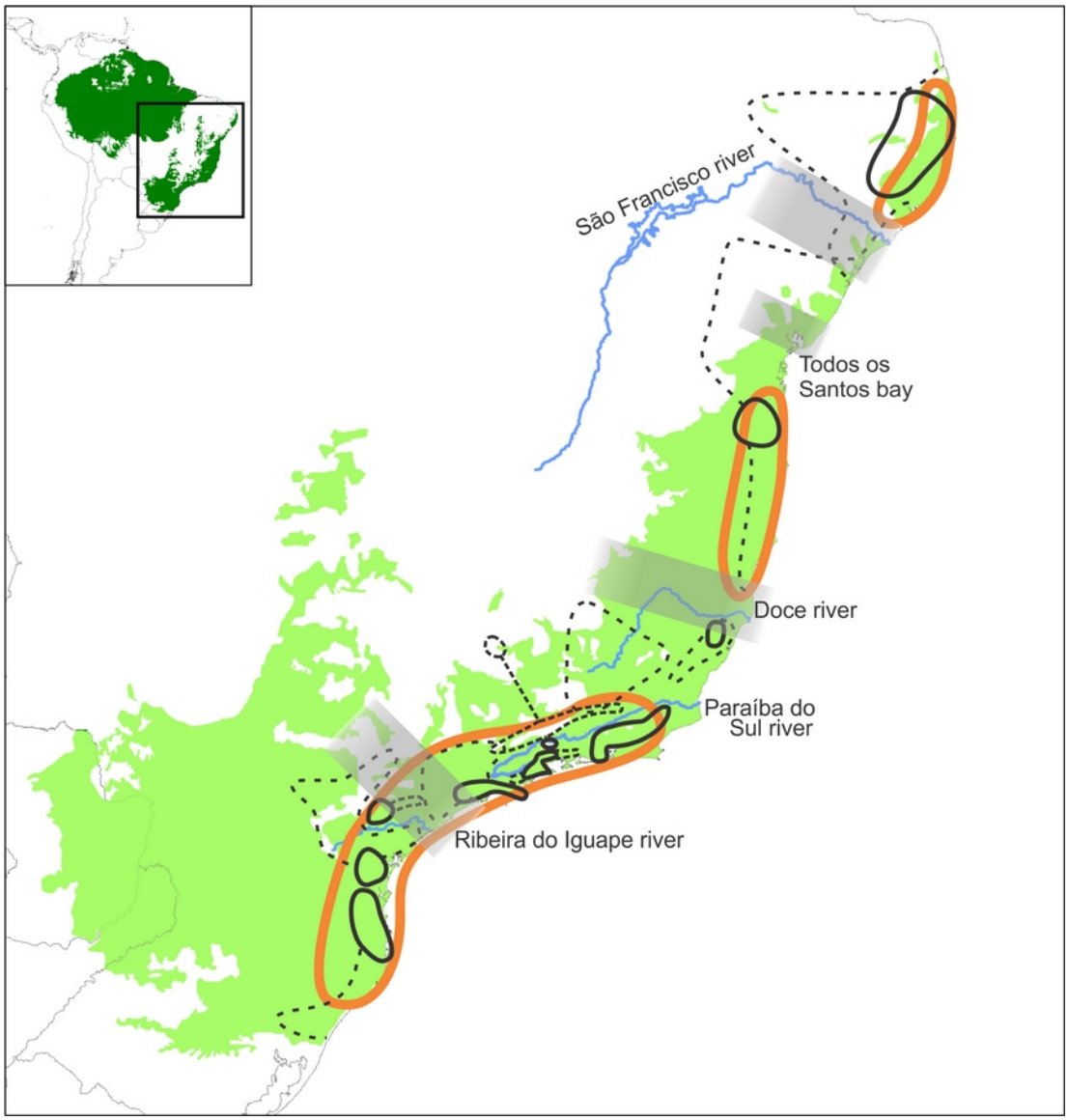


Fig. 1. General spatial pattern of historical breaks of Atlantic Forest for several taxa. In wide orange lines, congruence of AoE of most works in literature (north to south, Pernambuco, Bahia and Serra do Mar AoEs, see references in the text); in black lines, areas of endemism for harvestmen ([25], full line is Congruence Cores, pointed black line is Maximum Region of Endemism). Gray bands represent main divisions as inferred from phylogeography, panbiogeography, cladistic biogeography and systematics of many works in literature.

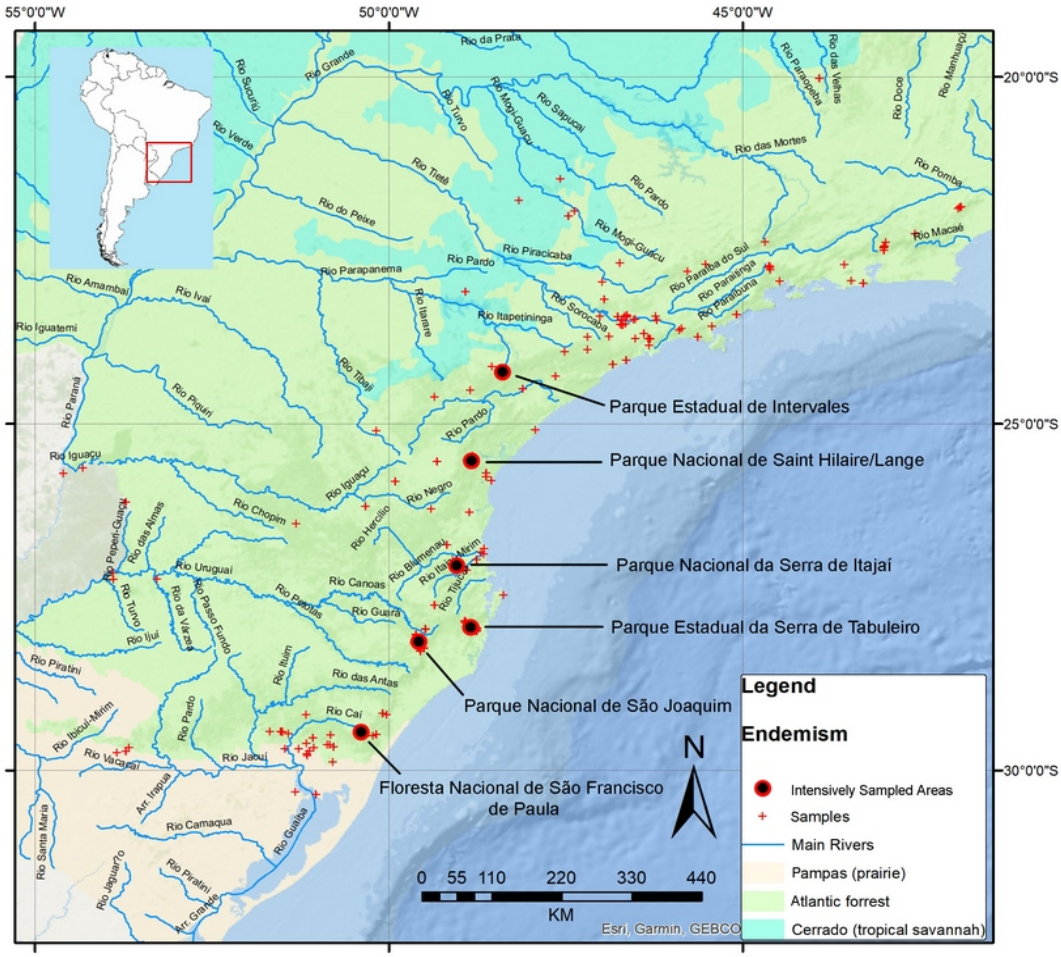


Fig. 2. Localities intensively sampled (~200 person-hour of sampling) in the Atlantic Forest. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

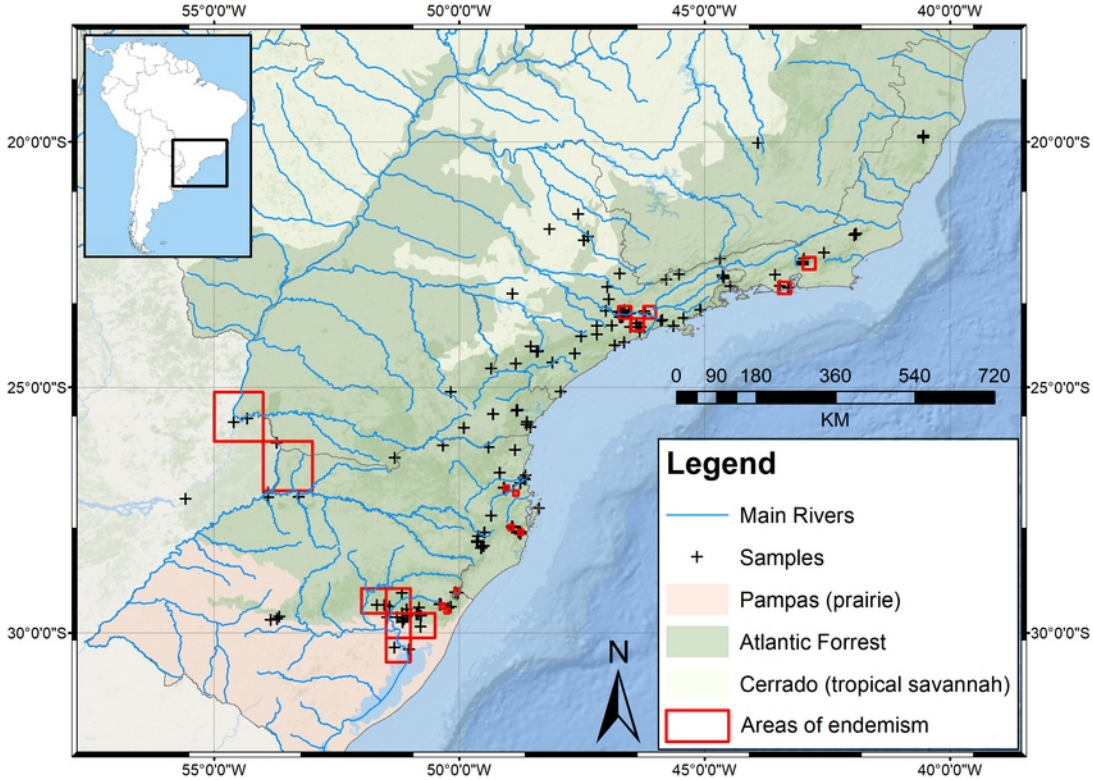


Fig. 3. Endemicity Analysis results obtained with 0.1º cell size grids, 0.25º cell size grids, 0.5º cell size grids, and 1º cell size grids. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

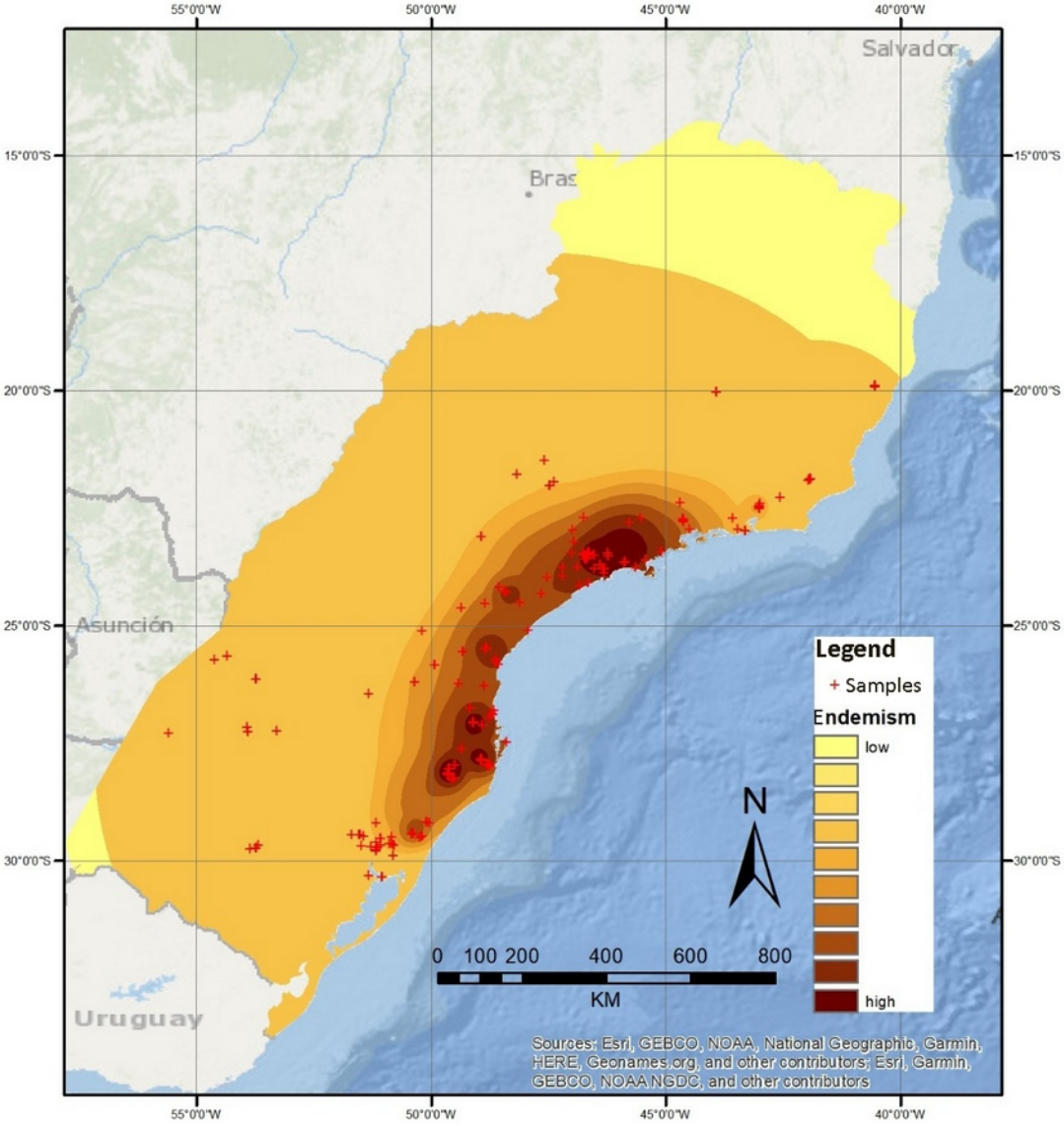


Fig. 4. Geographic Interpolation of Enedemism results obtained with five normalized categories (each category in the analysis has the same influence) over a topographic map. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

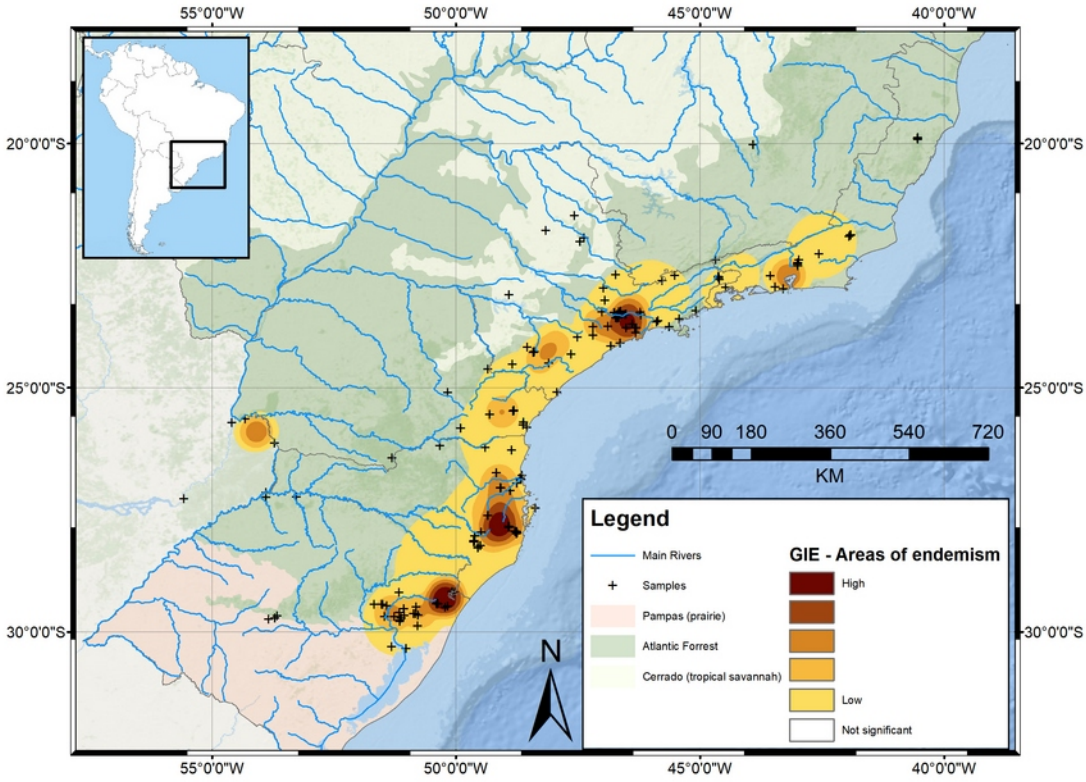


Fig. 5. Geographic Interpolation of Endemism results obtained with five categories, with the predefined weight given by the GIE tool set (Oliveira *et al.*, 2015) over a topographic map, Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

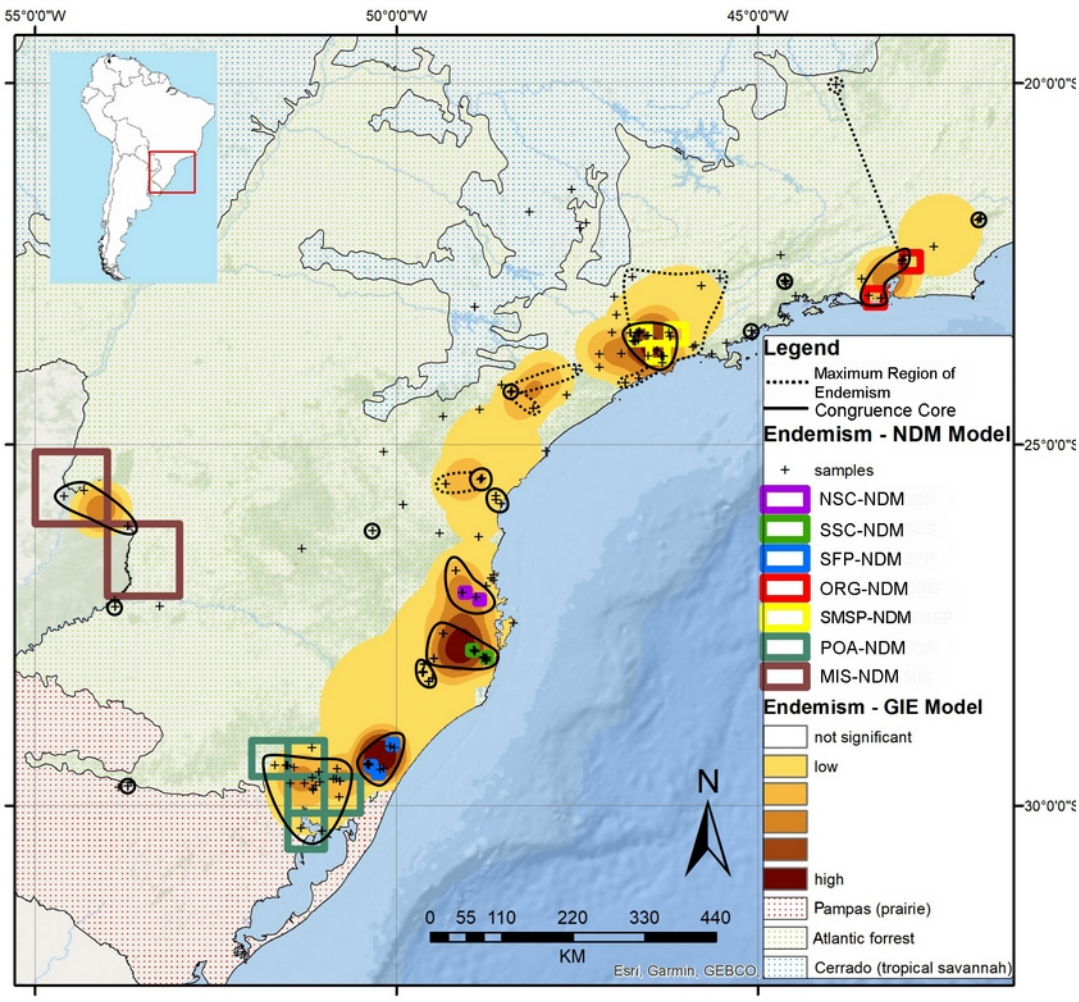


Fig. 6. Topographical map showing AoE identified in this study through the different methodologies used. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

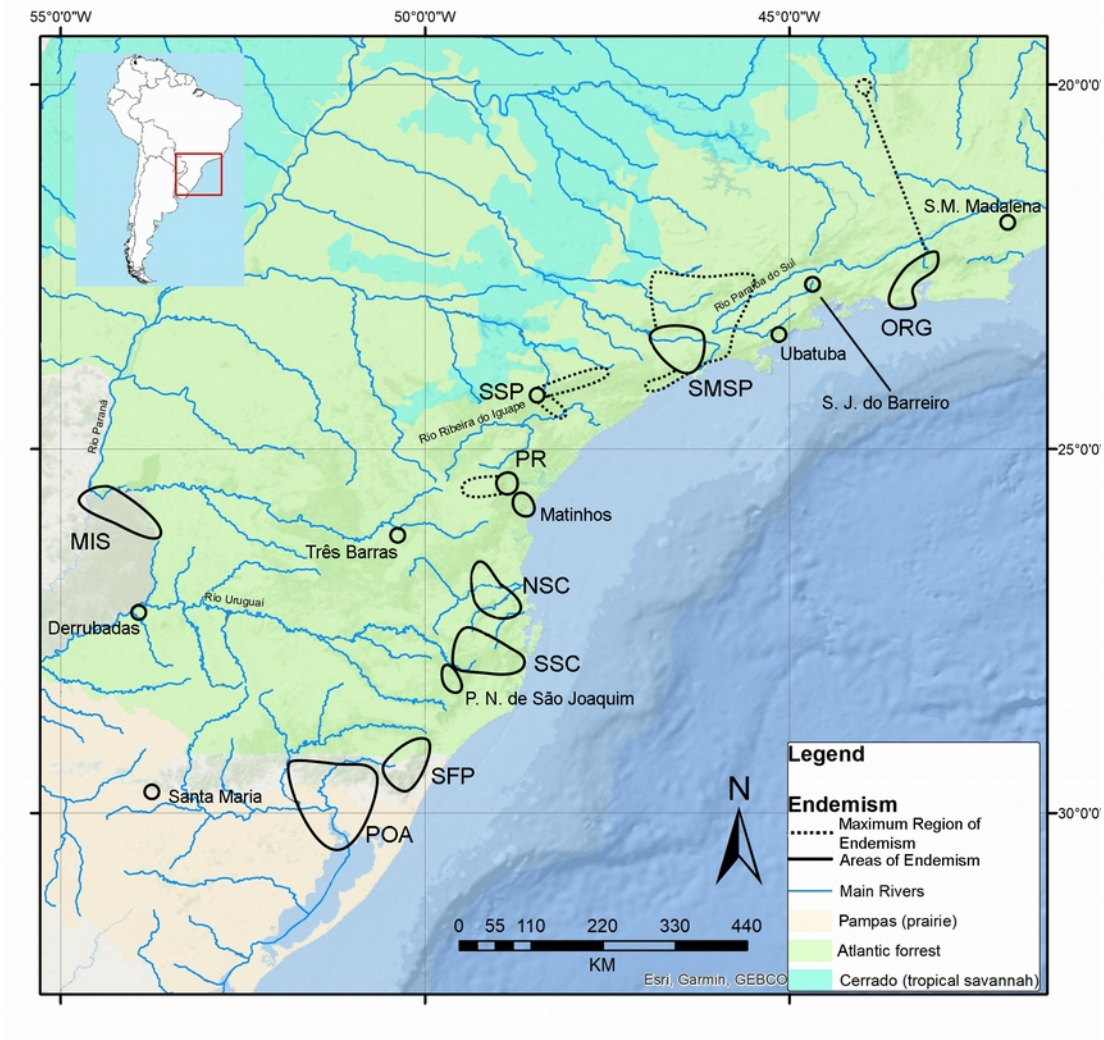
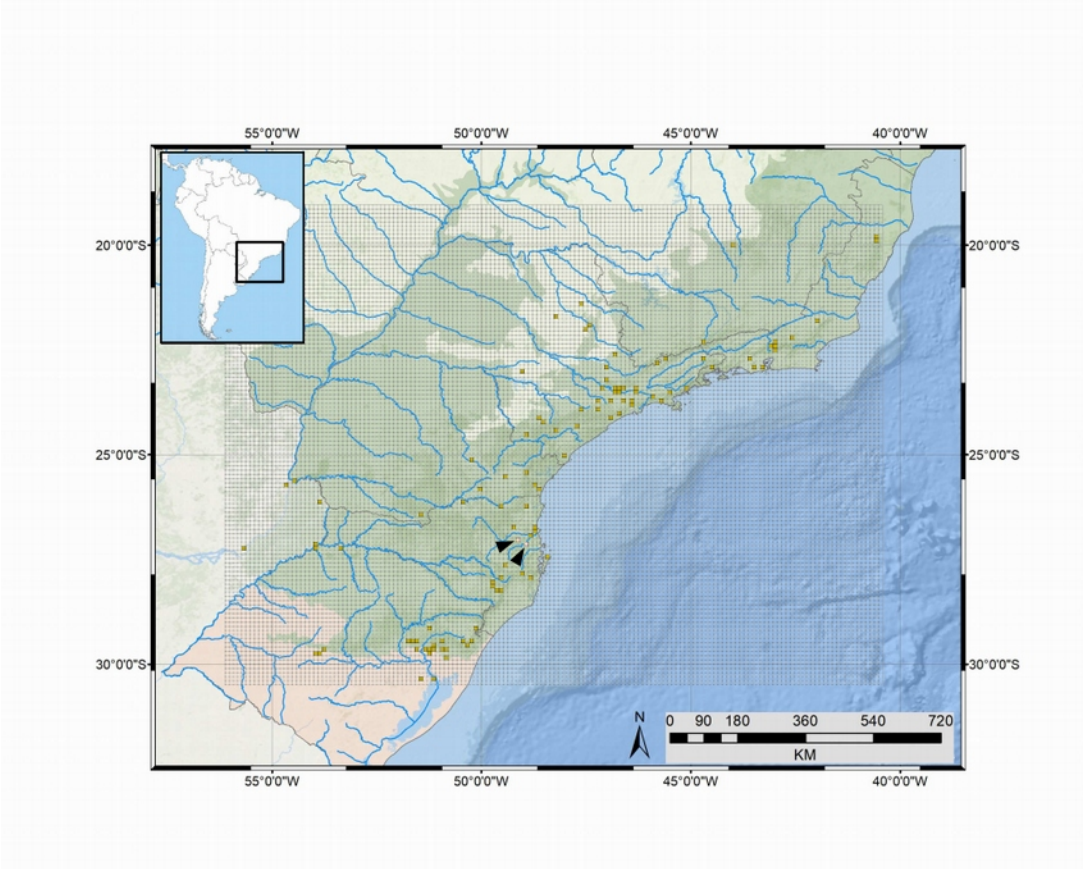


Fig. 7. Delimitation of AoE of land planarians, on a topographical map of the Atlantic Forest region.Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

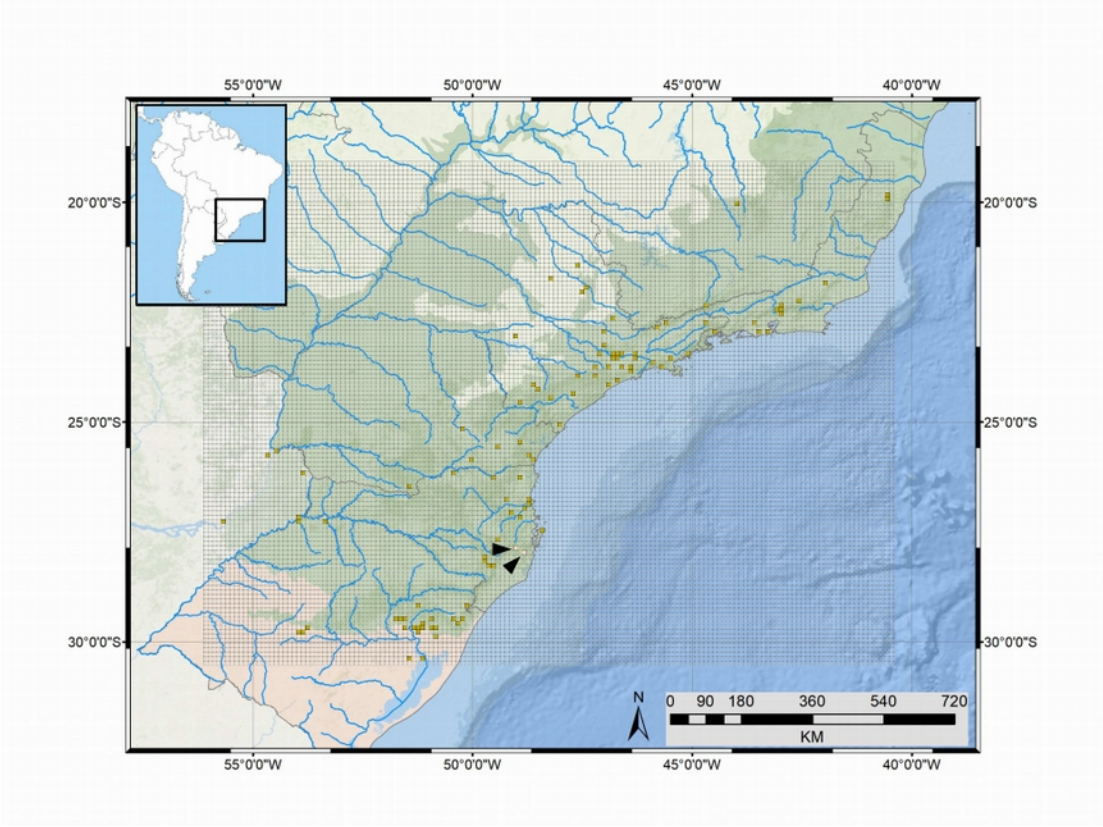
AoE	EA (cell size that identified the AoE)	GIE	Species in a CC represented by > 1 record	Species in a CC represented by a Single record	Species contributing to the MRE	Species exclusive to the AoE	WS
ORG	0.25, 0.5	Yes	30	26	2	32	18
SMSP	0.25, 0.3, 0.5	Yes	18	15	6	24	14
SSP	-	Yes	15	15	3	18	13
PR	-	Yes	10	10	1	11	9
NSC	0.1, 0.25	Merged with SSC	12	10	0	12	18
SSC	0.1, 0.25, 0.3	Merged with NSC	23	18	0	23	16
SFP	0.1, 0.25, 0.3	Merged with POA	25	20	0	25	13
POA	0.5	Merged with SFP	4	1	0	4	12
MIS	1.0	Yes	6	4	0	6	0

Tab. 1. The nine Areas of Endemism (AoE) discovered through Endemicity analysis (EA) and/or Geographic Interpolation Endemism (GIE). For EA, the cell sizes through which EA discovered AoE are indicated. The Table also informs the number of flatworm species according to different classification criteria. CC: Congruence Core; MRE: Maximum Region of Endemism. See text for details.

Supplementary Material

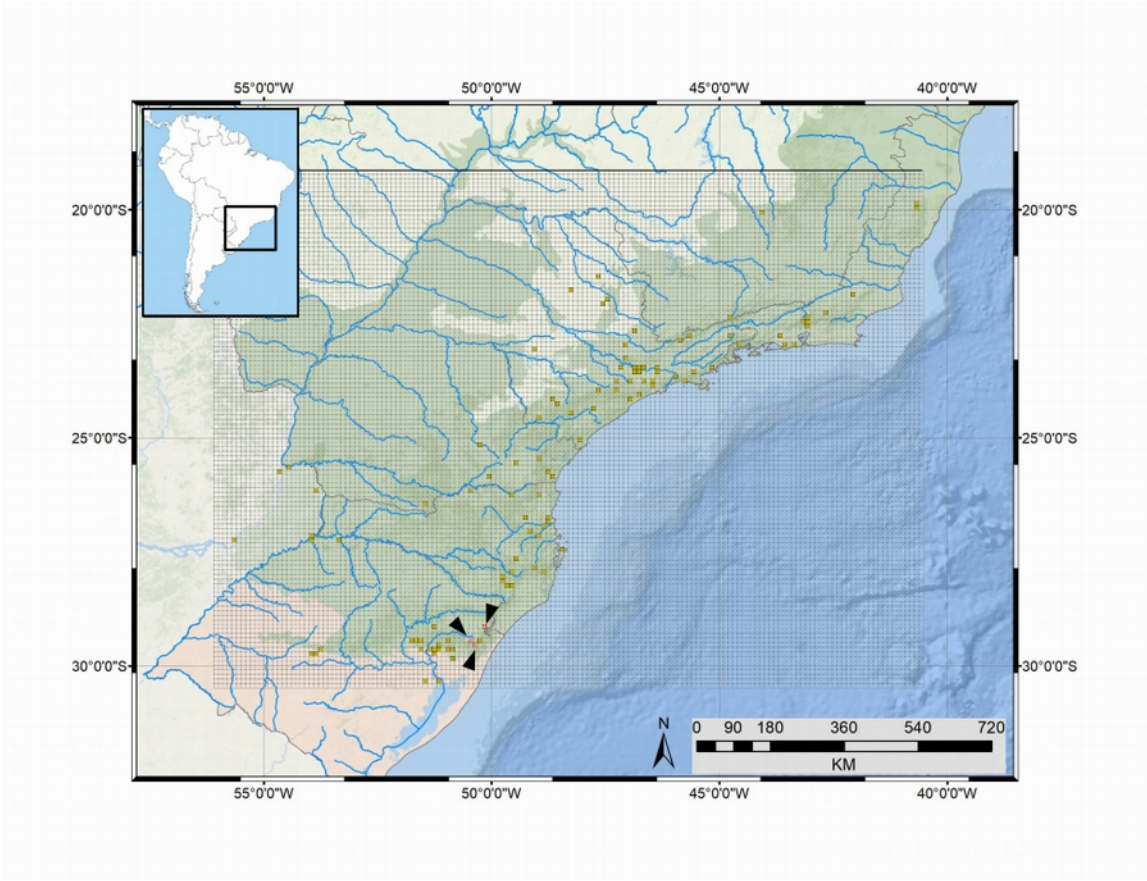


S1 Fig. Consensus-set North Santa Catarina obtained with NDM/VNDM.
Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Pasipha velina* (Froehlich, 1959) (Endemicity Index of 1.000), *Choeradoplana langi* (Graff, 1894) (Endemicity Index of 1.000).



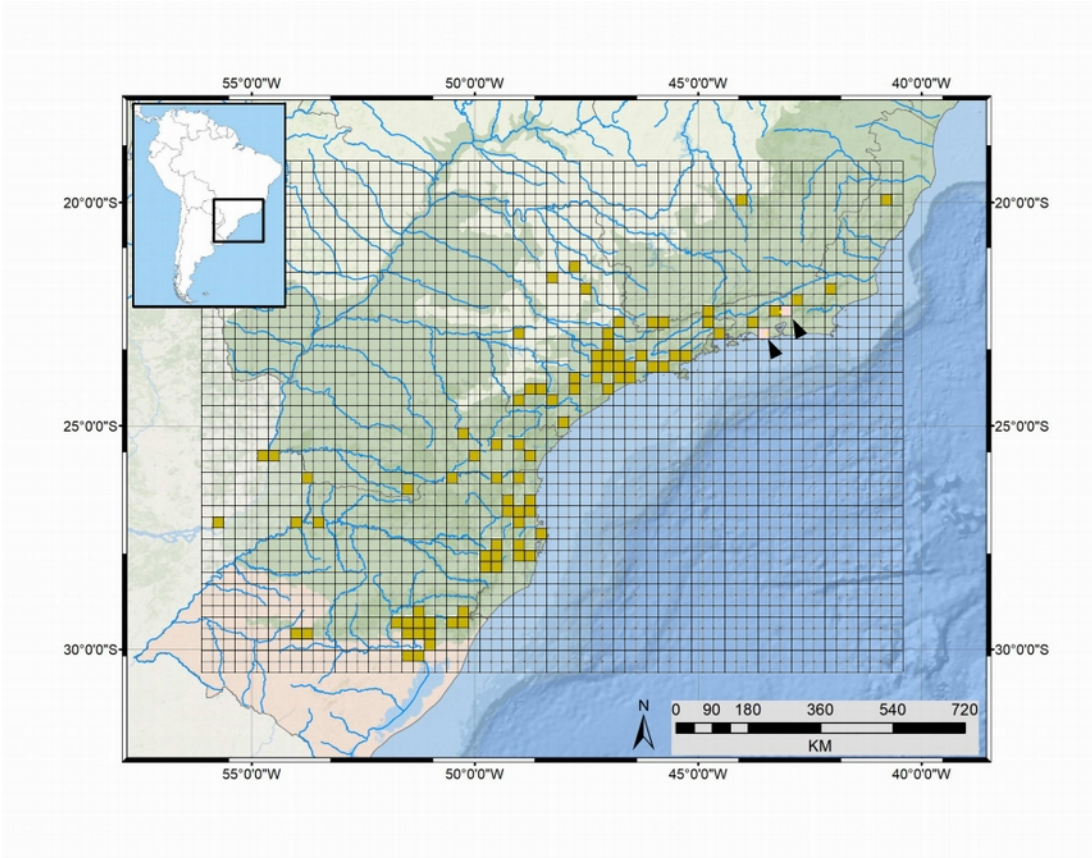
S2 Fig. Consensus-set South Santa Catarina obtained with NDM/VNDM.

Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Paraba tingauna* (Kishimoto & Carbayo, 2012) (Endemicity Index of 1.000), *Choeradoplana abaiba* Carbayo et al., 2017 (Endemicity Index of 1.000).

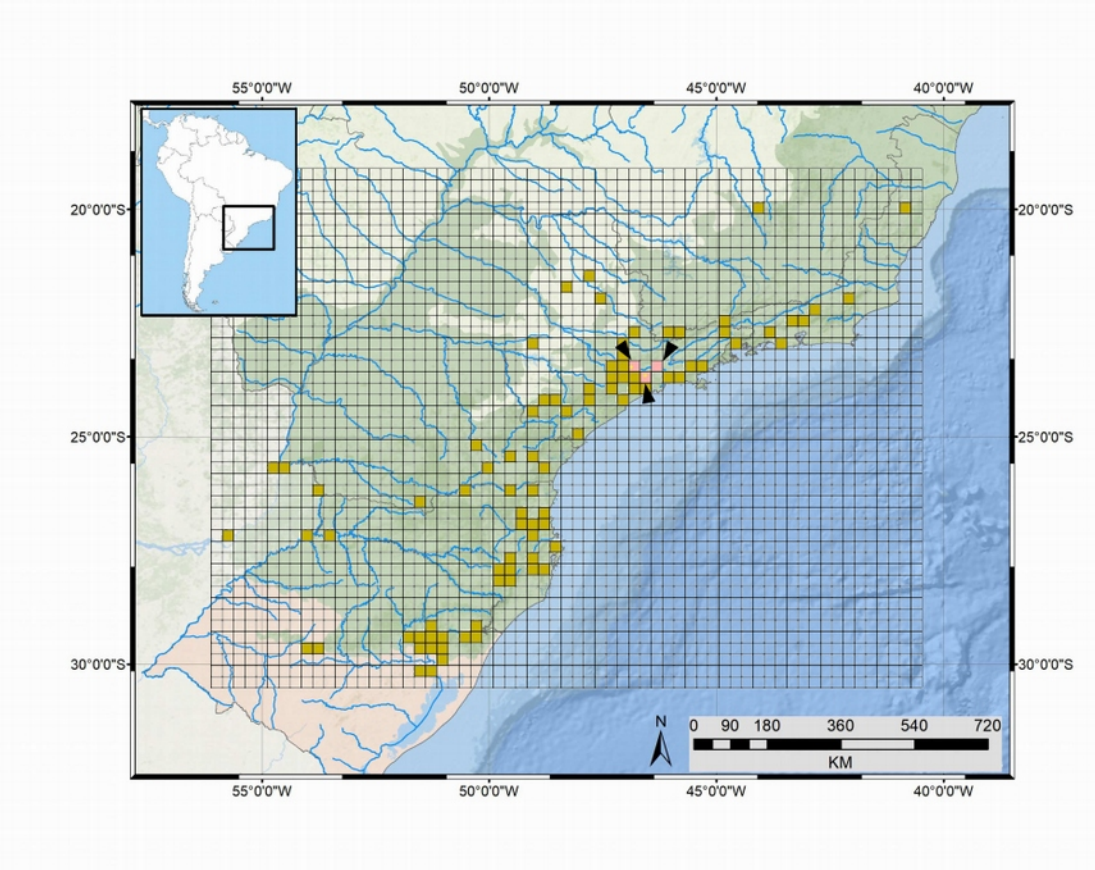


S3 Fig. Consensus-set São Francisco de Paula obtained with NDM/VNDM.

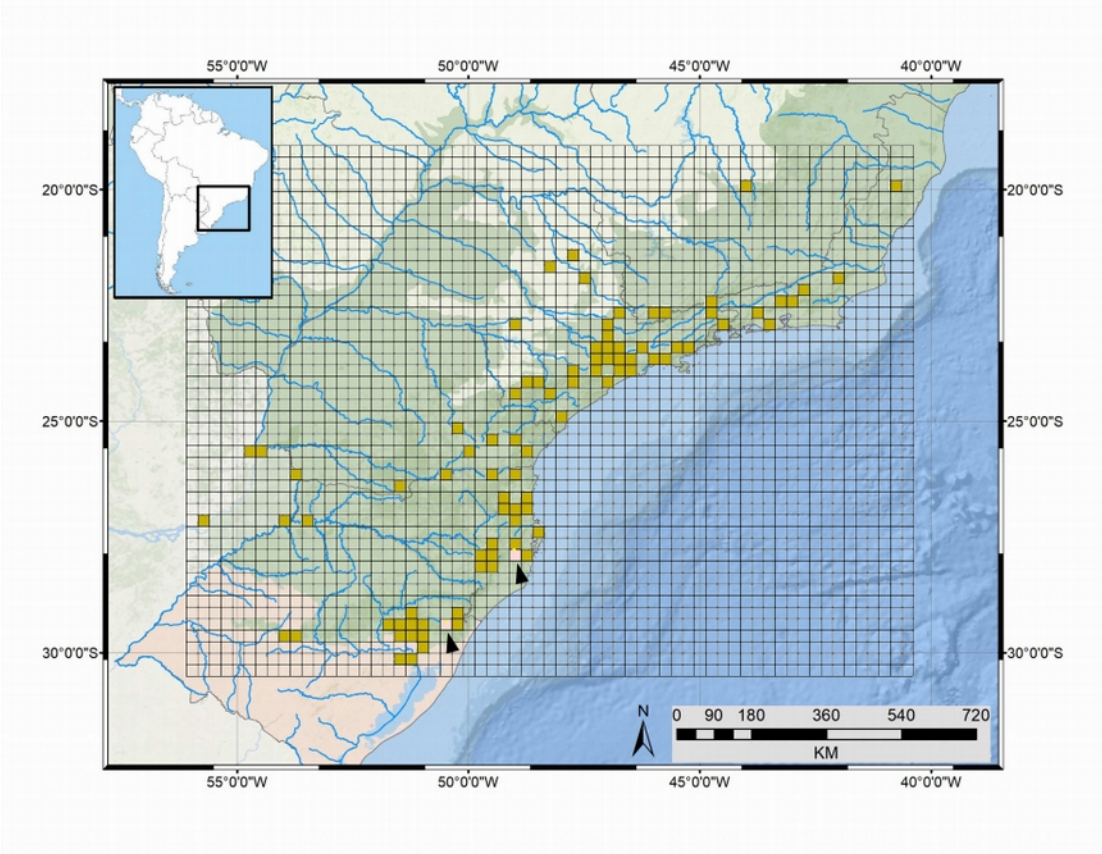
Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Luteostriata ceciliae* (Froehlich & Leal-Zanchet, 2003) (Endemicity Index of 0.833–1.000), *Obama josefi* (Carbayo & Leal-Zanchet, 2001) (Endemicity Index of 0.000–0.500), *Paraba franciscana* (Leal-Zanchet & Carbayo, 2001) (Endemicity Index of 0.000–0.500), *Luteostriata arturi* (Lemos & Leal-Zanchet, 2008) (Endemicity Index of 0.833–1.000), *Obama maculipunctata* Rossi *et al*., 2016 (Endemicity Index of 0.833–1.000).



S4 Fig. Consensus-set Serra dos Órgãos obtained with NDM/VNDM.Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Obama fryi* (*Graff*, *1899*) (Endemicity Index of 1.000), *Geoplana vaginuloides* (Darwin, 1844) (Endemicity Index of 1.000).

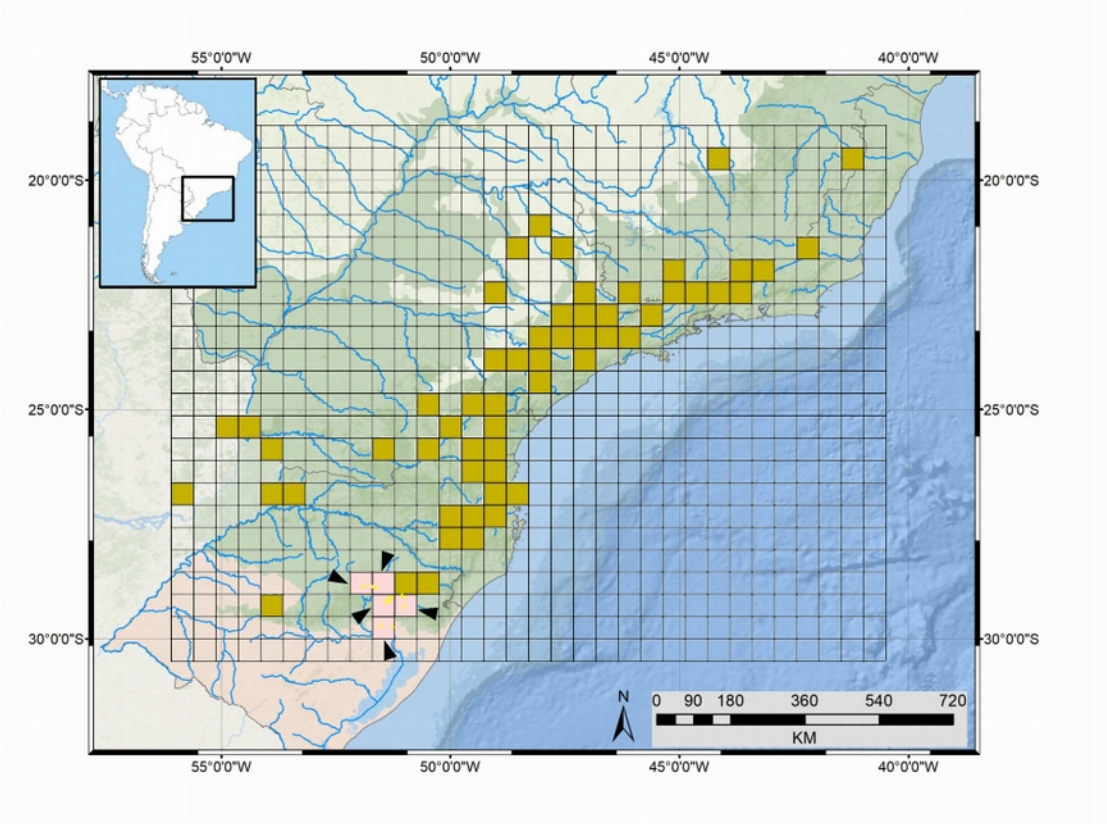


S5 Fig. Consensus-set Serra do Mar de São Paulo obtained with NDM/VNDM. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Obama metzi* (Graff, 1899) (Endemicity Index of 0.000–0.833), *Geoplana duca* Marcus, 1951 (Endemicity Index of 0.833–1.000), *Geoplana mogi* Almeida & Carbayo, 2019 (Endemicity Index of 0.833–1.000).



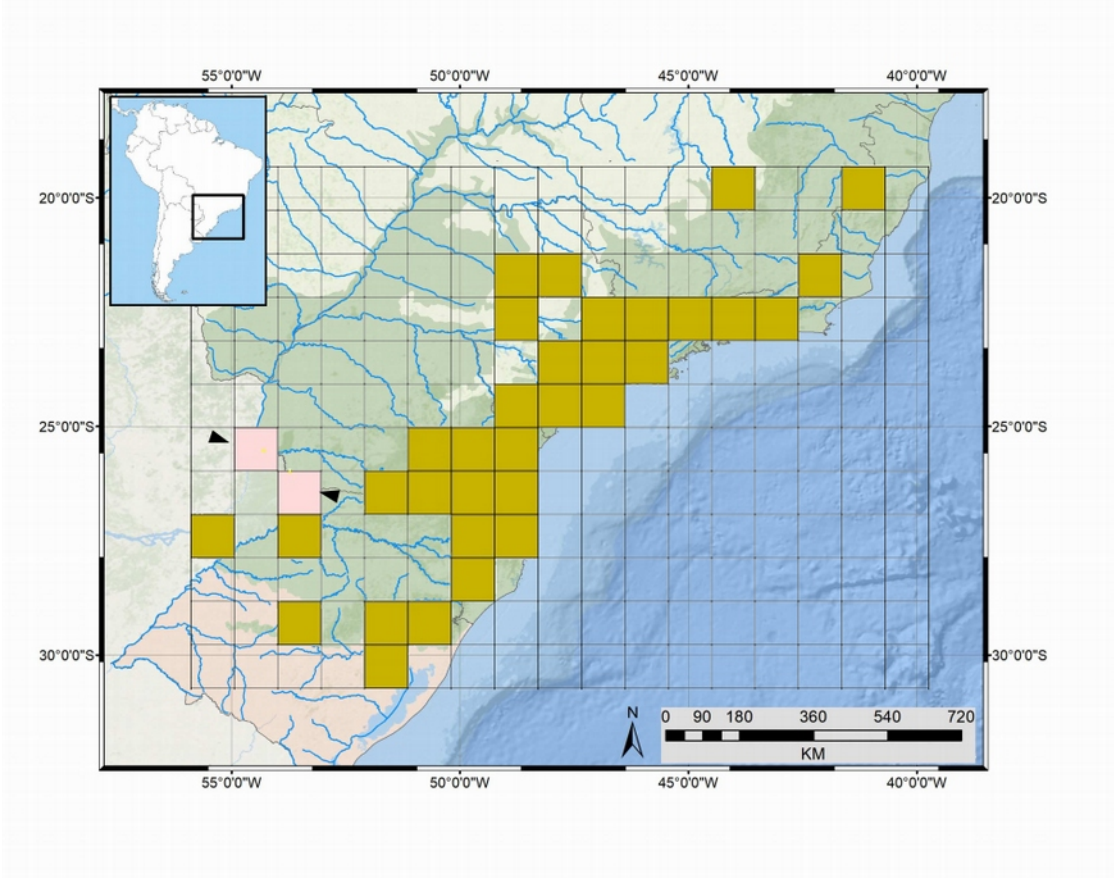
S6 Fig. Disjunct consensus-set which overlaps with other sets previously generated (South Santa Catarina and São Francisco de Paula) obtained with NDM/VNDM.

Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Choeradoplana benyai* Lemos & Leal-Zanchet, 2014 (Endemicity Index of 1.000), *Imbira sp. 1* (Endemicity Index of 1.000).



S7 Fig. Consensus-set Porto Alegre obtained with NDM/VNDM.

Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Luteostriata abundans* (Graff, 1899) (Endemicity Index of 0.429–1.000), *Paraba gaucha* (Froehlich, 1959) (Endemicity Index of 0.800–1.000), *Pasipha hauseri* (Froehlich, 1959) (Endemicity Index of 0.700–0.833).



S8 Fig. Consensus-set Misiones obtained with NDM/VNDM.

Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), pink cells (pointed with arrowheads) represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. Species giving score in pink cells: *Supramontana argentina* Negrete et al., 2012 (Endemicity Index of 1.000), *Pasipha mbya* Negrete & Brusa, 2016 (Endemicity Index of 1.000).

S1 Table. Geographic coordinates of the species used in the study.

Data comes from literature (reference given) and our own unpublished records (a voucher specimen is mentioned as well as the way the specimen was identified). 'Name of sp. in EA' reffers to the name given to each species in the analysis.

Reference or voucher specimen of the record	**Morph-ological identifi-cation**	**Locality**	**Name of sp. in EA**	***Scientific name***	**Latitude**	**Longitude**	**Country**
Lago-Barcia & Carbayo (2018)	-	Ribeirão Grande/ SP	sp 0	*Cratera arucuia*	-24.2693	-48.4054	Brazil
Amaral et al 2018	-	Maquiné/RS	sp 1	*Imbira flavonigra*	-29.501444	-50.221056	Brazil
Negrete & Brusa (2017)	-	San Ignacio	sp 2	*Pasipha quirogai*	-27.27944	-55.57861	Argentina
Negrete & Brusa (2017)	-	Moconá Provincial Park, Misiones province, Argentina	sp 3	*Imbira negrita*	-27.14889	-53.898333	Argentina
Froehlich & Leal-Zanchet, 2003	-	São Francisco de Paula/RS	sp 4	*Luteostriata ceciliae*	-29.428944	-50.392000	Brazil
Leal-Zanchet et al (2011)	-	Cambará do Sul/ RS	sp 4	*Luteostriata ceciliae*	-29.179104	-50.080631	Brazil
Carbayo et al (2016)	-	Paulo Lopes/SC	sp 5	*Obama marmorata*	-27.84278	-48.92583	Brazil
Carbayo et al (2016)	-	São Bonifácio/SC	sp 5	*Obama marmorata*	-27.84278	-48.92583	Brazil
Carbayo et al (2016)	-	Paulo Lopes/SC	sp 5	*Obama marmorata*	-27.95869	-48.76164	Brazil
F4620	External	PN Itajaí	sp 5	*Obama marmorata*	-27.05386	-49.08606	Brazil
F7401	External	PN São Joaquim	sp 5	*Obama marmorata*	-28.235882	-49.498872	Brazil
Froehlich (1959)	-	Rio do Testo/SC	sp 5	*Obama marmorata*	-26.743720	-49.175644	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 5	*Obama marmorata*	-27.05386	-49.08606	Brazil
Carbayo (2010)	-	Penha/SC	sp 6	*Luteostriata muelleri*	-26.80	-48.65	Brazil
Carbayo (2010)	-	Navegantes/SC	sp 6	*Luteostriata muelleri*	-26.85	-48.69	Brazil
Carbayo (2010)	-	Itajaí/SC	sp 6	*Luteostriata muelleri*	-26.88	-48.66	Brazil
Carbayo et al (2013)	-	São Bonifácio/SC	sp 6	*Luteostriata muelleri*	-27.84278	-48.92583	Brazil
F1588	External and AC	PN Itajaí	sp 6	*Luteostriata muelleri*	-27.05306	-49.08528	Brazil
F3284	External	PE Tabuleiro	sp 6	*Luteostriata muelleri*	-27.840735	-48.924866	Brazil
Froehlich (1959)	-	Rio do Testo/SC	sp 6	*Luteostriata muelleri*	-26.743720	-49.175644	Brazil
Froehlich (1959)	-	Brusque/SC	sp 6	*Luteostriata muelleri*	-27.111325	-48.895427	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 6	*Luteostriata muelleri*	-27.05386	-49.08606	Brazil
Amaral et al (2014)	-	Poço das Antas/RS	sp 7	*Luteostriata abundans*	-29.44	-51.68	Brazil
Amaral et al (2014)	-	Salvador do Sul/ RS	sp 7	*Luteostriata abundans*	-29.442428	-51.502151	Brazil
Amaral et al (2014)	-	Tupandi/RS	sp 7	*Luteostriata abundans*	-29.47	-51.42	Brazil
Amaral et al (2014)	-	Taquara/RS	sp 7	*Luteostriata abundans*	-29.659801	-50.779542	Brazil
Amaral et al (2014)	-	Campo Bom/RS	sp 7	*Luteostriata abundans*	-29.67	-51.06	Brazil
Amaral et al (2014)	-	Novo Hamburgo/ RS	sp 7	*Luteostriata abundans*	-29.72	-51.12	Brazil
Amaral et al (2014)	-	Glorinha/RS	sp 7	*Luteostriata abundans*	-29.88	-50.79	Brazil
Antunes et al (2008)	-	Viamão/RS	sp 7	*Luteostriata abundans*	-30.345738	-51.027817	Brazil
Carbayo (2010)	-	Barra do Ribeiro/ RS	sp 7	*Luteostriata abundans*	-30.31	-51.32	Brazil
Carbayo et al (2013)	-	Parobé/RS	sp 7	*Luteostriata abundans*	-29.62940	-50.83110	Brazil
Carbayo et al (2013)	-	São Leopoldo/RS	sp 7	*Luteostriata abundans*	-29.78828	-51.15084	Brazil
Froehlich (1959)	-	São Leopoldo/RS	sp 7	*Luteostriata abundans*	-29.764171	-51.155840	Brazil
Froehlich (1959)	-	São Leopoldo/RS	sp 8	*Geoplana carrierei sensu Marcus, 1951*	-29.764171	-51.155840	Brazil
Marcus (1951)	-	São Paulo/SP	sp 8	*Geoplana carrierei sensu Marcus, 1951*	-23.561966	-46.656958	Brazil
Marcus (1951)	-	Santo André/SP	sp 8	*Geoplana carrierei sensu Marcus, 1951*	-23.773397	-46.333248	Brazil

Álvarez-Presas et al (2015)	-	São Bonifácio/SC	sp 9	*Obama ladislavii*	-27.84278	-48.92583	Brazil
Álvarez-Presas et al (2015)	-	Montenegro/RS	sp 9	*Obama ladislavii*	-29.688889	-51.466944	Brazil
Amaral et al (2014)	-	Salvador do Sul/ RS	sp 9	*Obama ladislavii*	-29.442428	-51.502151	Brazil
Antunes et al (2008)	-	Viamão/RS	sp 9	*Obama ladislavii*	-30.345738	-51.027817	Brazil
Antunes et al (2012)	-	São Francisco de Paula/RS	sp 9	*Obama ladislavii*	-29.428944	-50.392000	Brazil
Baptista et al (2006)	-	Cambará do Sul/ RS	sp 9	*Obama ladislavii*	-29.179104	-50.080631	Brazil
Castro & Leal_Zanchet (2005)	-	Arroio Grande/RS	sp 9	*Obama ladislavii*	-29.672918	-53.668858	Brazil
F3262	External	PE Tabuleiro	sp 9	*Obama ladislavii*	-27.840735	-48.924866	Brazil
F6545	External	Alfredo Wagner	sp 9	*Obama ladislavii*	-24.61695	-49.35075	Brazil
F7357	External	PN São Joaquim	sp 9	*Obama ladislavii*	-28.038956	-49.614243	Brazil
Froehlich (1959)	-	São Leopoldo/RS	sp 9	*Obama ladislavii*	-29.764171	-51.155840	Brazil
Graff (1899)	-	Blumenau/SC	sp 9	*Obama ladislavii*	-27.05386	-49.08606	Brazil
Graff (1899)	-	Taquara/RS	sp 9	*Obama ladislavii*	-29.659801	-50.779542	Brazil
F1465	External, F and AC	PNItajai	sp 10	*Xerapoa pseudorhynchodemus*	-27.05306	-49.08528	Brazil
F1708	External	Saint-Hilaire	sp 10	*Xerapoa pseudorhynchodemus*	-25.469604	-48.813739	Brazil
F3350	External and AC	PE Tabuleiro	sp 10	*Xerapoa pseudorhynchodemus*	-27.840735	-48.924866	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 10	*Xerapoa pseudorhynchodemus*	-27.05386	-49.08606	Brazil
Marcus (1951)	-	São Paulo/SP	sp 10	*Xerapoa pseudorhynchodemus*	-23.500212	-46.702310	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 10	*Xerapoa pseudorhynchodemus*	-22.439089	-42.994351	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 11	*Geoplana quagga*	-22.439089	-42.994351	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 11	*Geoplana quagga*	-27.05386	-49.08606	Brazil
Marcus (1951)	-	São Paulo/SP	sp 11	*Geoplana quagga*	-23.577633	-46.701739	Brazil
Carbayo et al (2013)	-	São Paulo/SP	sp 12	*Pasipha tapetilla*	-23.46047	-46.63672	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 12	*Pasipha tapetilla*	-22.500057	-42.997365	Brazil
CG Froehlich (1956a)	-	Rio de Janeiro/RJ	sp 12	*Pasipha tapetilla*	-22.975852	-43.292230	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 12	*Pasipha tapetilla*	-23.423381	-45.083399	Brazil
F1405	External and AC	PNItajai	sp 12	*Pasipha tapetilla*	-27.05306	-49.08528	Brazil
F3201	External	PE Tabuleiro	sp 12	*Pasipha tapetilla*	-27.94	-48.79	Brazil
Froehlich (1959)	-	Itajaí/SC	sp 12	*Pasipha tapetilla*	-26.957485	-48.756133	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 12	*Pasipha tapetilla*	-27.05386	-49.08606	Brazil
Marcus (1951)	-	Pirassununga/SP	sp 12	*Pasipha tapetilla*	-22.007522	-47.459448	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 13	*Pasipha velina*	-27.05386	-49.08606	Brazil
Froehlich (1959)	-	Brusque/SC	sp 13	*Pasipha velina*	-27.111325	-48.895427	Brazil
F3287	External, F and AC	PE Tabuleiro	sp 14	*Obama apeva*	-27.840735	-48.924866	Brazil
F6512	External	Alfredo Wagner/ SC	sp 14	*Obama apeva*	-27.61727	-49.35075	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 14	*Obama apeva*	-27.05386	-49.08606	Brazil
Froehlich (1959)	-	Brusque/SC	sp 14	*Obama apeva*	-27.111325	-48.895427	Brazil
Froehlich (1959)	-	Rio do Testo/SC	sp 15	*Obama assu*	-26.743720	-49.175644	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 15	*Obama assu*	-27.05386	-49.08606	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 16	*Luteostriata fita*	-27.05386	-49.08606	Brazil
Antunes et al (2008)	-	São Leopoldo/RS	sp 17	*Paraba gaucha*	-29.764171	-51.155840	Brazil
Antunes et al (2008)	-	Viamão/RS	sp 17	*Paraba gaucha*	-30.345738	-51.027817	Brazil
Froehlich (1959)	-	Salvador do Sul/ RS	sp 17	*Paraba gaucha*	-29.436817	-51.527611	Brazil
froehlich (1959)	-	Iraí/RS	sp 18	*Obama glieschi*	-27.242571	-53.272863	Brazil
Amaral et al (2014)	-	Salvador do Sul/ RS	sp 19	*Pasipha hauseri*	-29.436817	-51.527611	Brazil
Froehlich (1959)	-	São Leopoldo/RS	sp 19	*Pasipha hauseri*	-29.764171	-51.155840	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 20	*Cephaloflexa nataliae*	-27.05386	-49.08606	Brazil
Froehlich (1959)	-	Blumenau/SC	sp 21	*Paraba suva*	-27.05386	-49.08606	Brazil

F1634	External, A1, F and AC	Saint-Hilaire	sp 22	*Luteostriata sp 4*	-25.71	-48.62	Brazil
Froehlich (1959)	-	Lapa/PR	sp 23	*Notogynaphallia atra*	-25.834333	-49.904062	Brazil
Froehlich (1959)	-	Rio do Testo/SC	sp 23	*Notogynaphallia atra*	-26.743720	-49.175644	Brazil
Froehlich (1959)	-	Itajaí/SC	sp 23	*Notogynaphallia atra*	-26.957485	-48.756133	Brazil
Froehlich (1959)	-	Brusque/SC	sp 23	*Notogynaphallia atra*	-27.111325	-48.895427	Brazil
Graff (1899)	-	Taquara/RS	sp 23	*Notogynaphallia atra*	-29.659801	-50.779542	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 23	*Notogynaphallia atra*	-27.05386	-49.08606	Brazil
Graff (1899)	-	Taquara/RS	sp 24	*Geoplana nigra*	-29.659801	-50.779542	Brazil
Álvarez-Presas et al (2011)	-	São José do Barreiro/SP	sp 25	*Cephaloflexa bergi*	-22.72583	-44.62611	Brazil
Álvarez-Presas et al (2014)	-	Santa Teresa/ES	sp 25	*Cephaloflexa bergi*	-19.8781	-40.5385	Brazil
Álvarez-Presas et al (2014)	-	Santa Teresa/ES	sp 25	*Cephaloflexa bergi*	-19.8875	-40.5362	Brazil
Álvarez-Presas et al (2014)	-	Santa Teresa/ES	sp 25	*Cephaloflexa bergi*	-19.9123	-40.5362	Brazil
Álvarez-Presas et al (2014)	-	Santa Maria Madalena/RJ	sp 25	*Cephaloflexa bergi*	-21.8735	-41.9142	Brazil
Álvarez-Presas et al (2014)	-	Santa Maria Madalena/RJ	sp 25	*Cephaloflexa bergi*	-21.8768	-41.9228	Brazil
Álvarez-Presas et al (2014)	-	Teresópolis/RJ	sp 25	*Cephaloflexa bergi*	-22.4558	-42.9963	Brazil
Álvarez-Presas et al (2014)	-	Campos do Jordão/SP	sp 25	*Cephaloflexa bergi*	-22.8039	-45.7768	Brazil
Álvarez-Presas et al (2014)	-	São Paulo/SP	sp 25	*Cephaloflexa bergi*	-23.4300	-46.6333	Brazil
Álvarez-Presas et al (2014)	-	Salesópolis/SP	sp 25	*Cephaloflexa bergi*	-23.6527	-45.8909	Brazil
Álvarez-Presas et al (2014)	-	Ribeirão Grande/ SP	sp 25	*Cephaloflexa bergi*	-24.2749	-48.4162	Brazil
Álvarez-Presas et al (2014)	-	São Bonifácio/SC	sp 25	*Cephaloflexa bergi*	-27.8417	-48.9254	Brazil
Álvarez-Presas et al (2014)	-	Paulo Lopes/SC	sp 25	*Cephaloflexa bergi*	-27.9568	-48.7735	Brazil
Baptista et al (2006)	-	Cambará do Sul/ RS	sp 25	*Cephaloflexa bergi*	-29.179104	-50.080631	Brazil
Carbayo et al (2013)	-	São Sebastião/SP	sp 25	*Cephaloflexa bergi*	-23.75203	-45.631027	Brazil
F1387	External and AC	PN Itajaí	sp 25	*Cephaloflexa bergi*	-27.04836	-49.09206	Brazil
F1664	External, F and AC	PN Itajai	sp 25	*Cephaloflexa bergi*	-25.469604	-48.813739	Brazil
F3088	External	PE Intervales	sp 25	*Cephaloflexa bergi*	-24.269387	-48.405467	Brazil
F3236	External and AC	PE Tabuleiro	sp 25	*Cephaloflexa bergi*	-27.84	-48.92	Brazil
F3257	External	PE Tabuleiro	sp 25	*Cephaloflexa bergi*	-27.9813889	-48.748055555	Brazil
F3611	External, F and AC	PN Saint Hilaire	sp 25	*Cephaloflexa bergi*	-25.469604	-48.813739	Brazil
F7275	External, A1 and AC	PN São Joaquim	sp 25	*Cephaloflexa bergi*	-28.041154	-49.615693	Brazil
F7442	External	PN São Joaquim	sp 25	*Cephaloflexa bergi*	-27.959870	-49.482576	Brazil
Froehlich (1956a)	-	Ubatuba/SP	sp 25	*Cephaloflexa bergi*	-23.423381	-45.083399	Brazil
Froehlich (1956b)	-	Morretes/PR	sp 25	*Cephaloflexa bergi*	-25.483460	-48.832020	Brazil
Froehlich (1956b)	-	Curitiba/PR	sp 25	*Cephaloflexa bergi*	-25.548339	-49.313845	Brazil
Froehlich (1956b)	-	Blumenau/SC	sp 25	*Cephaloflexa bergi*	-27.05386	-49.08606	Brazil
Carbayo et al (2016)	-	Teresópolis/RJ	sp 26	*Obama burmeisteri*	-22.439089	-42.994351	Brazil
Carbayo et al (2016)	-	Jundiaí/SP	sp 26	*Obama burmeisteri*	-23.21	-46.95	Brazil
CG Froehlich (1956a)	-	Rio de Janeiro/RJ	sp 26	*Obama burmeisteri*	-22.975852	-43.292230	Brazil
Froehlich (1956a)	-	Ubatuba/SP	sp 26	*Obama burmeisteri*	-23.423381	-45.083399	Brazil
Froehlich (1956b)	-	Matinhos/PR	sp 26	*Obama burmeisteri*	-25.817820	-48.549932	Brazil
Froehlich (1956b)	-	Itajaí/SC	sp 26	*Obama burmeisteri*	-26.957485	-48.756133	Brazil
Froehlich (1956b)	-	Blumenau/SC	sp 26	*Obama burmeisteri*	-27.05386	-49.08606	Brazil

Froehlich (1956b)	-	Brusque/SC	sp 26	*Obama burmeisteri*	-27.111325	-48.895427	Brazil
Graff (1899)	-	Morro Reuter/RS	sp 26	*Obama burmeisteri*	-29.53	-51.07	Brazil
Marcus (1951)	-	São Paulo/SP	sp 26	*Obama burmeisteri*	-23.500212	-46.702310	Brazil
Carbayo et al (2013)	-	São José do Barreiro/SP	sp 27	*Paraba multicolor*	-22.72583	-44.62611	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 27	*Paraba multicolor*	-22.439089	-42.994351	Brazil
F2646	External and AC	PE Intervales	sp 27	*Paraba multicolor*	-24.269387	-48.405467	Brazil
F3301	External, F and AC	PE Tabuleiro	sp 27	*Paraba multicolor*	-27.840735	-48.924866	Brazil
F7317	External	PN São Joaquim	sp 27	*Paraba multicolor*	-28.040421	-49.615316	Brazil
Froehlich (1956b)	-	Curitiba/PR	sp 27	*Paraba multicolor*	-25.548339	-49.313845	Brazil
Froehlich (1956b)	-	Lapa/PR	sp 27	*Paraba multicolor*	-25.834333	-49.904062	Brazil
Froehlich (1957)	-	Guapiara/SP	sp 27	*Paraba multicolor*	-24.173828	-48.542533	Brazil
Froehlich (1957)	-	Ponta Grossa/PR	sp 27	*Paraba multicolor*	-25.101490	-50.174131	Brazil
Leal-Zanchet & Matos (2011)	-	Caxias do Sul/RS	sp 27	*Paraba multicolor*	-29.194212	-51.165792	Brazil
Leal-Zanchet & Matos (2011)	-	Ibarama/RS	sp 27	*Paraba multicolor*	-29.722778	-53.714177	Brazil
Leal-Zanchet & Matos (2011)	-	Santa Maria/RS	sp 27	*Paraba multicolor*	-29.722778	-53.714177	Brazil
Marcus (1951)	-	Avaré/SP	sp 27	*Paraba multicolor*	-23.096206	-48.914060	Brazil
Marcus (1951)	-	São Paulo/SP	sp 27	*Paraba multicolor*	-23.453148	-46.634488	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 27	*Paraba multicolor*	-23.505856	-46.211903	Brazil
Marcus (1951)	-	Santo André/SP	sp 27	*Paraba multicolor*	-23.773397	-46.333248	Brazil
F1619	External, F and AC	Saint-Hilaire	sp 28	*Obama polyophthalma*	-25.71	-48.62	Brazil
Froehlich (1956b)	-	Caiobá/PR	sp 28	*Obama polyophthalma*	-25.817820	-48.549932	Brazil
Froehlich (1956b)	-	Rio do Testo/SC	sp 28	*Obama polyophthalma*	-26.743720	-49.175644	Brazil
Graff (1899)	-	Joinville/SC	sp 28	*Obama polyophthalma*	-26.28	-48.86	Brazil
Graff (1899)	-	Blumenau/SC	sp 28	*Obama polyophthalma*	-27.05386	-49.08606	Brazil
Graff (1899)	-	Taquara/RS	sp 28	*Obama polyophthalma*	-29.659801	-50.779542	Brazil
Carbayo et al (2013)	-	Ribeirão Grande/ SP	sp 29	*Obama carinata*	-24.26	-48.40	Brazil
F3122	External, A2, A3, F and AC	PE Intervales	sp 29	*Obama carinata*	-24.269387	-48.405467	Brazil
Froehlich (1956b)	-	Morretes/PR	sp 29	*Obama carinata*	-25.483460	-48.832020	Brazil
Froehlich (1956b)	-	Curitiba/PR	sp 29	*Obama carinata*	-25.548339	-49.313845	Brazil
Froehlich (1957)	-	Pirassununga/SP	sp 29	*Obama carinata*	-21.934693	-47.372714	Brazil
Froehlich (1957)	-	Itapecerica da Serra/SP	sp 29	*Obama carinata*	-23.741677	-46.886010	Brazil
Froehlich (1957)	-	Juquiá/SP	sp 29	*Obama carinata*	-24.317073	-47.639867	Brazil
Marcus (1951)	-	São Paulo/SP	sp 29	*Obama carinata*	-23.453148	-46.634488	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 29	*Obama carinata*	-23.505856	-46.211903	Brazil
Marcus (1951)	-	Mongaguá/SP	sp 29	*Obama carinata*	-24.085174	-46.640241	Brazil
Marcus (1951)	-	Eldorado/SP	sp 29	*Obama carinata*	-24.498352	-48.103028	Brazil
Riester (1938)	-	Ribeirão Pires/SP	sp 29	*Obama carinata*	-23.701329	-46.39	Brazil
Carbayo et al (2013)	-	São Bernardo/SP	sp 30	*Pasipha rosea*	-23.77368	-46.51469	Brazil
EM Froehlich (1955a)	-	Pirassununga/SP	sp 30	*Pasipha rosea*	-22.007522	-47.459448	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 30	*Pasipha rosea*	-23.453148	-46.634488	Brazil
Froehlich (1956b)	-	Lapa/PR	sp 30	*Pasipha rosea*	-25.834333	-49.904062	Brazil
Froehlich (1957)	-	São Simão	sp 30	*Pasipha rosea*	-21.471847	-47.573321	Brazil
F2032	External and AC	São José do Barreiro/SP	Sp 30	*Pasipha rosea*	-22.78222	-44.60583	Brazil
Froehlich (1956b)	-	Morretes/PR	sp 31	*Cratera joia*	-25.483460	-48.832020	Brazil
Froehlich (1956b)	-	Morretes/PR	sp 32	*Notogynaphallia mourei*	-25.483460	-48.832020	Brazil
Froehlich (1956b)	-	Curitiba/PR	sp 32	*Notogynaphallia mourei*	-25.548339	-49.313845	Brazil
Carbayo et al (2013)	-	Ribeirão Grande/ SP	sp 33	*Notogynaphallia plumbea*	-24.27638	-48.41556	Brazil
F1627	External and F	PN Saint Hilaire	sp 33	*Notogynaphallia plumbea*	-25.469604	-48.813739	Brazil
F3085	External, F and AC	PE Intervales	sp 33	*Notogynaphallia plumbea*	-24.269387	-48.405467	Brazil

F3229	External, A1, F and AC	PE Tabuleiro	sp 33	*Notogynaphallia plumbea*	-27.9813889	-48.748055555	Brazil
Froehlich (1956b)	-	São Paulo/SP	sp 33	*Notogynaphallia plumbea*	-23.459300	-46.755164	Brazil
Froehlich (1956b)	-	Morretes/PR	sp 33	*Notogynaphallia plumbea*	-25.483460	-48.832020	Brazil
Almeida et al (2018)	-	Alfredo Wagner/ SC	sp 34	*Geoplana pulchella*	-27.61695	-49.34778	Brazil
Almeida et al (2018)	-	Paulo Lopes/SC	sp 34	*Geoplana pulchella*	-27.98139	-48.74806	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 34	*Geoplana pulchella*	-27.05386	-49.08606	Brazil
Froehlich (1955b)	-	Teresópolis/RJ	sp 35	*Pasipha splendida*	-22.439089	-42.994351	Brazil
Froehlich (1955b)	-	Teresópolis/RJ	sp 36	*Pasipha oliverioi*	-22.439089	-42.994351	Brazil
Froehlich (1955b)	-	Teresópolis/RJ	sp 37	*Geoplana fragai*	-22.439089	-42.994351	Brazil
Froehlich (1955b)	-	Teresópolis/RJ	sp 38	*Geoplana jandira*	-22.439089	-42.994351	Brazil
Froehlich (1957)	-	Amparo/SP	sp 39	*Obama braunsi*	-22.682420	-46.732935	Brazil
Graff (1899)	-	São Paulo/SP	sp 39	*Obama braunsi*	-23.459300	-46.755164	Brazil
Graff (1899)	-	Santos/SP	sp 39	*Obama braunsi*	-23.87	-46.32	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 39	*Obama braunsi*	-23.505856	-46.211903	Brazil
F4624	External, F and AC	PN Itajaí	sp 40	*Paraba caapora*	-27.05386	-49.08606	Brazil
Froehlich (1957)	-	Apiaí/SP	sp 40	*Paraba caapora*	-24.518261	-48.844379	Brazil
Froehlich (1957)	-	Itanhaém/SP	sp 41	*Obama poca*	-24.148182	-46.830256	Brazil
Froehlich (1957)	-	São Paulo/SP	sp 42	*Obama schubarti*	-23.459300	-46.755164	Brazil
Froehlich (1957)	-	Itanhaém/SP	sp 42	*Obama schubarti*	-24.148182	-46.830256	Brazil
F3797	External and AC	PE Intervales	sp 43	*Paraba tapira*	-24.269387	-48.405467	Brazil
Froehlich (1957)	-	Tapiraí/SP	sp 43	*Paraba tapira*	-23.964151	-47.512885	Brazil
Froehlich (1957)	-	Juquiá/SP	sp 44	*Geoplana toriba*	-24.317073	-47.639867	Brazil
F3136	External and all internal	PE Intervales	sp 45	*Issoca potyra*	-24.269387	-48.405467	Brazil
Froehlich (1957)	-	Eldorado/SP	sp 45	*Issoca potyra*	-24.498352	-48.103028	Brazil
Amaral et al (2012)	-	Praia Grande/SC	sp 46	*Obama ficki*	-29.198086	-50.026672	Brazil
Amaral et al (2012)	-	São Francisco de Paula/RS	sp 46	*Obama ficki*	-29.428944	-50.392000	Brazil
Amaral et al (2014)	-	Salvador do Sul/ RS	sp 46	*Obama ficki*	-29.442428	-51.502151	Brazil
F7380	External	PN São Joaquim	sp 46	*Obama ficki*	-28.235930	-49.498947	Brazil
F7258	External and AC	PN São Joaquim	sp 47	*Obama* sp. 14	-28.156986	-49.637516	Brazil
F7372	External and AC	PN São Joaquim	sp 48	*Cratera* sp. 5	-28.162100	-49.626466	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 49	*Paraba preta*	-22.439089	-42.994351	Brazil
Carbayo et al (2013)	-	São Leopoldo/RS	sp 50	*Geobia subterranea*	-29.764171	-51.155840	Brazil
CG Froehlich (1955)	-	São Paulo/SP	sp 50	*Geobia subterranea*	-23.448030	-46.666767	Brazil
F3608	External	Saint-Hilaire	sp 50	*Geobia subterranea*	-25.71	-48.62	Brazil
Marcus (1951)	-	Avaré/SP	sp 50	*Geobia subterranea*	-23.096206	-48.914060	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 50	*Geobia subterranea*	-23.505856	-46.211903	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 50	*Geobia subterranea*	-22.439089	-42.994351	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 50	*Geobia subterranea*	-27.05386	-49.08606	Brazil
Carbayo et al (2017)	-	Salesópolis/SP	sp 51	*Choeradoplana marthae*	-23.63	-45.86	Brazil
CG Froehlich (1955)	-	Mongaguá/SP	sp 51	*Choeradoplana marthae*	-24.085174	-46.640241	Brazil
CG Froehlich (1955)	-	Teresópolis/RJ	sp 52	*Choeradoplana catua*	-22.439089	-42.994351	Brazil
CG Froehlich (1955)	-	Ubatuba/SP	sp 53	*Issoca rezendei*	-23.423381	-45.083399	Brazil
CG Froehlich (1955)	-	Mongaguá/SP	sp 53	*Issoca rezendei*	-24.085174	-46.640241	Brazil
CG Froehlich (1955)	-	Itanhaém/SP	sp 53	*Issoca rezendei*	-24.148182	-46.830256	Brazil
CG Froehlich (1955)	-	Itajaí/SC	sp 53	*Issoca rezendei*	-26.957485	-48.756133	Brazil
CG Froehlich (1955)	-	Blumenau/SC	sp 53	*Issoca rezendei*	-27.05386	-49.08606	Brazil
F3595	External and AC	Saint-Hilaire	sp 53	*Issoca rezendei*	-25.469604	-48.813739	Brazil

Marcus (1951)	-	São Paulo/SP	sp 53	*Issoca rezendei*	-23.578104	-46.689043	Brazil
Schirch (1929)	-	Teresópolis/RJ	sp 53	*Issoca rezendei*	-22.500057	-42.997365	Brazil
Carbayo et al (2013)	-	São José do Barreiro/SP	sp 54	*Issoca jandaia*	-22.78222	-44.60583	Brazil
CG Froehlich (1955)	-	Monte Jaraguá	sp 54	*Issoca jandaia*	-23.459736	-46.761403	Brazil
F2689	External, f and AC	PE Intervales	sp 54	*Issoca jandaia*	-24.269387	-48.405467	Brazil
CG Froehlich (1955)	-	Teresópolis/RJ	sp 55	*Issoca piranga*	-22.439089	-42.994351	Brazil
CG Froehlich (1955)	-	São Paulo/SP	sp 56	*Xerapoa hystrix*	-23.453148	-46.634488	Brazil
CG Froehlich (1955)	-	Mogi das Cruzes/ SP	sp 56	*Xerapoa hystrix*	-23.505856	-46.211903	Brazil
CG Froehlich (1955)	-	Curitiba/PR	sp 56	*Xerapoa hystrix*	-25.548339	-49.313845	Brazil
CG Froehlich (1955)	-	Brusque/SC	sp 57	*Xerapoa una*	-27.111325	-48.895427	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 58	*Obama applanata*	-22.439089	-42.994351	Brazil
Carbayo et al (2013)	-	São Paulo/SP	sp 59	*Notogynaphallia sexstriata*	-23.56671	-46.73017	Brazil
Carbayo et al (2013)	-	Blumenau/SC	sp 59	*Notogynaphallia sexstriata*	-27.04836	-49.09200	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 59	*Notogynaphallia sexstriata*	-22.439089	-42.994351	Brazil
du Bois Reymond-Marcus (1951)	-	Brusque/SC	sp 59	*Notogynaphallia sexstriata*	-27.111325	-48.895427	Brazil
du Bois Reymond-Marcus (1951)	-	Taquara/RS	sp 59	*Notogynaphallia sexstriata*	-29.659801	-50.779542	Brazil
F1413	External, F and AC	PNItajai	sp 59	*Notogynaphallia sexstriata*	-27.05306	-49.08528	Brazil
F1741	External, A1 and AC	Saint-Hilaire	sp 59	*Notogynaphallia sexstriata*	-25.469604	-48.813739	Brazil
Schirch (1929)	-	Teresópolis/RJ	sp 60	*Paraba goettei*	-22.439089	-42.994351	Brazil
Schirch (1929)	-	Teresópolis/RJ	sp 61	*Pasipha plana*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 62	*Cratera pseudovaginuloides*	-22.439089	-42.994351	Brazil
Carbayo (2010)	-	Ribeirão Pires/SP	sp 63	*Luteostriata caissara*	-23.701329	-46.39	Brazil
Carbayo (2010)	-	Itanhaém/SP	sp 63	*Luteostriata caissara*	-24.148182	-46.830256	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 63	*Luteostriata caissara*	-22.439089	-42.994351	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 63	*Luteostriata caissara*	-22.500057	-42.997365	Brazil
CG Froehlich (1956a)	-	Rio de Janeiro/RJ	sp 63	*Luteostriata caissara*	-22.975852	-43.292230	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 63	*Luteostriata caissara*	-23.423381	-45.083399	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 64	*Paraba cassula*	-22.439089	-42.994351	Brazil
Carbayo et al (2017)	-	Santa Maria Madalena/RJ	sp 65	*Matuxia matuta*	-21.87	-41.91	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 65	*Matuxia matuta*	-22.439089	-42.994351	Brazil
Carbayo et al (2016)	-	Teresópolis/RJ	sp 66	*Cratera tamoia*	-22.46447	-43.00278	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 66	*Cratera tamoia*	-22.439089	-42.994351	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 66	*Cratera tamoia*	-22.500057	-42.997365	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 67	*Obama trigueira*	-22.439089	-42.994351	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 67	*Obama trigueira*	-22.500057	-42.997365	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 68	*Cratera yara*	-22.439089	-42.994351	Brazil
F6897	External and all internal	Saint-Hilaire	sp 69	*Pasipha* sp. 7	-25.469604	-48.813739	Brazil
CG Froehlich (1956a)	-	Teresópolis/RJ	sp 70	*Rhynchodemus hectori*	-22.439089	-42.994351	Brazil
CG Froehlich (1956a)	-	Rio de Janeiro/RJ	sp 71	*Barreira barreirana*	-22.975852	-43.292230	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 71	*Barreira barreirana*	-23.423381	-45.083399	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 71	*Barreira barreirana*	-22.500057	-42.997365	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 72	*Barreira zebroides*	-22.500057	-42.997365	Brazil
Marcus (1951)	-	São Paulo/SP	sp 73	*Cratera taxiarcha*	-23.453148	-46.634488	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 74	*Pasipha cafusa*	-23.423381	-45.083399	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 75	*Geoplana picta*	-23.423381	-45.083399	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	sp 76	*Rhynchodemus scius*	-23.423381	-45.083399	Brazil
Carbayo et al (2013)	-	São José do Barreiro/SP	sp 272	*Pasipha* sp. 15	-22.73389	-44.61639	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 77	*Pasipha chimbeva*	-23.459736	-46.761403	Brazil
EM Froehlich (1955a)	-	Pirassununga/SP	sp 78	*Geoplana chiuna*	-22.007522	-47.459448	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 79	*Cratera crioula*	-23.453148	-46.634488	Brazil

EM Froehlich (1955a)	-	São Paulo/SP	sp 80	*Obama livia*	-23.453148	-46.634488	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 80	*Obama livia*	-23.459736	-46.761403	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 81	*Notogynaphallia parca*	-23.453148	-46.634488	Brazil
Carbayo et al (2013)	-	Teresópolis/RJ	sp 82	*Pasipha pinima*	-22.45528	-42.99750	Brazil
Carbayo et al (2013)	-	Morretes/PR	sp 82	*Pasipha pinima*	-25.46972	-48.81222	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 82	*Pasipha pinima*	-23.453148	-46.634488	Brazil
F2752	External and AC	PE Intervales	sp 82	*Pasipha pinima*	-24.269387	-48.405467	Brazil
F7296	External	PN São Joaquim	sp 82	*Pasipha pinima*	-28.041154	-49.615693	Brazil
EM Froehlich (1955a)	-	Araraquara/SP	sp 83	*Geoplana regia*	-21.779764	-48.161178	Brazil
Carbayo et al (2013)	-	Teresópolis/RJ	sp 84	*Matuxia tuxaua*	-22.45528	-42.99750	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 84	*Matuxia tuxaua*	-23.453148	-46.634488	Brazil
EM Froehlich (1955a)	-	São Paulo/SP	sp 84	*Matuxia tuxaua*	-23.459736	-46.761403	Brazil
Marcus (1951)	-	São Paulo/SP	sp 85	*Geoplana ferussaci sensu Riester, 1938*	-23.500212	-46.702310	Brazil
Riester (1938)	-	Nova Lima/MG	sp 85	*Geoplana ferussaci sensu Riester, 1938*	-20.02	-43.91	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 85	*Geoplana ferussaci sensu Riester, 1938*	-22.500057	-42.997365	Brazil
Marcus (1951)	-	São Paulo/SP	sp 86	*Obama metzi*	-23.500212	-46.702310	Brazil
Riester (1938)	-	Ribeirão Pires/SP	sp 86	*Obama metzi*	-23.701329	-46.39	Brazil
Álvarez-PResas et al (2011)	-	São José do Barreiro/SP	sp 87	*Imbira marcusi*	-22.72583	-44.62611	Brazil
F3161	External, F and AC	PE Intervales	sp 87	*Imbira marcusi*	-24.269387	-48.405467	Brazil
F3568	External and all internal	PN Saint Hilaire	sp 87	*Imbira marcusi*	-25.469604	-48.813739	Brazil
Marcus (1951)	-	São Paulo/SP	sp 87	*Imbira marcusi*	-23.500212	-46.702310	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 87	*Imbira marcusi*	-23.505856	-46.211903	Brazil
Marcus (1951)	-	Mongaguá/SP	sp 87	*Imbira marcusi*	-24.085174	-46.640241	Brazil
Marcus (1951)	-	São Paulo/SP	sp 88	*Pasipha astraea*	-23.500212	-46.702310	Brazil
F3084	External and AC	PE Intervales	sp 89	*Obama divae*	-24.269387	-48.405467	Brazil
Marcus (1951)	-	Santo André/SP	sp 89	*Obama divae*	-23.773397	-46.333248	Brazil
Marcus (1951)	-	São Paulo/SP	sp 90	*Geoplana duca*	-23.453148	-46.634488	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 90	*Geoplana duca*	-23.505856	-46.211903	Brazil
Marcus (1951)	-	Santo André/SP	sp 91	*Obama evelinae*	-23.773397	-46.333248	Brazil
Marcus (1951)	-	Mongaguá/SP	sp 91	*Obama evelinae*	-24.085174	-46.640241	Brazil
Marcus (1951)	-	Santo André/SP	sp 92	*Cratera hina*	-23.773397	-46.333248	Brazil
Marcus (1951)	-	São Paulo/SP	sp 93	*Pasipha pasipha*	-23.453148	-46.634488	Brazil
Marcus (1951)	-	Mogi das Cruzes/ SP	sp 94	*Geoplana pavani*	-23.505856	-46.211903	Brazil
Carbayo et al (2013)	-	São José do Barreiro/SP	sp 271	*Paraba* sp. 7	-22.73389	-44.61639	Brazil
Marcus (1951)	-	São Paulo/SP	sp 95	*Paraba phocaica*	-23.500212	-46.702310	Brazil
Carbayo et al (2013)	-	Teresópolis/RJ	sp 96	*Xerapoa trina*	-22.38455	-42.97681	Brazil
Carbayo et al (2013)	-	Teresópolis/RJ	sp 96	*Xerapoa trina*	-22.45528	-42.99750	Brazil
Marcus (1951)	-	Santo André/SP	sp 96	*Xerapoa trina*	-23.773397	-46.333248	Brazil
Marcus (1951)	-	Angra dos Reis/RJ	sp 97	*Choeradoplana bilix*	-22.946008	-44.474647	Brazil
Amaral et al (2012)	-	Derrubadas/RS	sp 98	*Obama carbayoi*	-27.247305	-53.893789	Brazil
Amaral et al (2012)	-	Santa Maria/RS	sp 99	*Obama baptistae*	-29.722778	-53.714177	Brazil
Amaral & Leal-Zanchet (2016)	-	Santa Maria/RS	sp 100	*Pasipha mesoxantha*	-29.722778	-53.714177	Brazil
Amaral & Leal-Zanchet (2016)	-	Derrubadas/RS	sp 101	*Pasipha turvensis*	-27.247305	-53.893789	Brazil
Carbayo (2010)	-	Pirassununga/SP	sp 102	*Luteostriata ernesti*	-22.007522	-47.459448	Brazil
Carbayo (2010)	-	Mogi das Cruzes/ SP	sp 102	*Luteostriata ernesti*	-23.505856	-46.211903	Brazil
Carbayo (2010)	-	Ibiúna/SP	sp 102	*Luteostriata ernesti*	-23.75	-47.19	Brazil
F3222	External	PE Tabuleiro	sp 102	*Luteostriata ernesti*	-27.94	-48.79	Brazil
Leal-Zanchet & Froehlich (2006)	-	Valinhos/SP	sp 102	*Luteostriata ernesti*	-22.96	-46.98	Brazil

Leal-Zanchet & Froehlich (2006)	-	Jundiaí/SP	sp 102	*Luteostriata ernesti*	-23.21	-46.95	Brazil
Leal-Zanchet & Froehlich (2006)	-	São Paulo/SP	sp 102	*Luteostriata ernesti*	-23.453148	-46.634488	Brazil
Leal-Zanchet & Froehlich (2006)	-	Ribeirão Pires/SP	sp 102	*Luteostriata ernesti*	-23.701329	-46.39	Brazil
Leal-Zanchet & Froehlich (2006)	-	Curitiba/PR	sp 102	*Luteostriata ernesti*	-25.548339	-49.313845	Brazil
Leal-Zanchet & Froehlich (2006)	-	São Francisco de Paula/RS	sp 102	*Luteostriata ernesti*	-29.428944	-50.392000	Brazil
Baptista et al (2006)	-	Cambará do Sul/ RS	sp 103	*Obama josefi*	-29.179104	-50.080631	Brazil
Carbayo & Leal-Zanchet (2001)	-	São Francisco de Paula/RS	sp 103	*Obama josefi*	-29.428944	-50.392000	Brazil
Leal-Zanchet et al (2011)	-	São Francisco de Paula/RS	sp 103	*Obama josefi*	-29.179104	-50.080631	Brazil
Leal-Zanchet et al (2011)	-	São Francisco de Paula/RS	sp 103	*Obama josefi*	-29.480590	-50.174679	Brazil
Almeida et al (2018)	-	Florianópolis/SC	sp 104	*Luteostriata graffi*	-27.468485	-48.377724	Brazil
Antunes et al (2012)	-	São Francisco de Paula/RS	sp 104	*Luteostriata graffi*	-29.428944	-50.392000	Brazil
Baptista et al (2006)	-	Cambará do Sul/ RS	sp 104	*Luteostriata graffi*	-29.179104	-50.080631	Brazil
Carbayo (2010)	-	Morro Reuter/RS	sp 104	*Luteostriata graffi*	-29.53	-51.07	Brazil
Carbayo (2010)	-	Parobé/RS	sp 104	*Luteostriata graffi*	-29.62940	-50.83110	Brazil
Leal-Zanchet & Froehlich (2006)	-	Salvador do Sul/ RS	sp 104	*Luteostriata graffi*	-29.442428	-51.502151	Brazil
Leal-Zanchet & Froehlich (2006)	-	Três Coroas/RS	sp 104	*Luteostriata graffi*	-29.49	-50.82	Brazil
Leal-Zanchet & Froehlich (2006)	-	Taquara/RS	sp 104	*Luteostriata graffi*	-29.659801	-50.779542	Brazil
Leal-Zanchet et al (2011)	-	São Francisco de Paula/RS	sp 104	*Luteostriata graffi*	-29.480590	-50.174679	Brazil
Carbayo & Leal-Zanchet (2003)	-	São Francisco de Paula/RS	sp 105	*Supramontana irritata*	-29.428944	-50.392000	Brazil
Baptista & Leal-Zanchet (2005)	-	São Francisco de Paula/RS	sp 106	*Paraba rubidolineata*	-29.428944	-50.392000	Brazil
Baptista et al (2010)	-	Derrubadas/RS	sp 106	*Paraba rubidolineata*	-27.247305	-53.893789	Brazil
F3271	External	PE Tabuleiro	sp 106	*Paraba rubidolineata*	-27.840735	-48.924866	Brazil
Baptista et al (2006)	-	Cambará do Sul/ RS	sp 107	*Paraba franciscana*	-29.179104	-50.080631	Brazil
Leal-Zanchet & Carbayo (2001)	-	São Francisco de Paula/RS	sp 107	*Paraba franciscana*	-29.428944	-50.392000	Brazil
Leal-Zanchet et al (2011)	-	São Francisco de Paula/RS	sp 107	*Paraba franciscana*	-29.480590	-50.174679	Brazil
Leal-Zanchet et al (2011)	-	Cambará do Sul/ RS	sp 108	*Luteostriata arturi*	-29.179104	-50.080631	Brazil
Lemos & Leal-Zanchet (2008)	-	São Francisco de Paula/RS	sp 108	*Luteostriata arturi*	-29.428944	-50.392000	Brazil
Leal-Zanchet et al (2012)	-	São Francisco de Paula/RS	sp 109	*Pasipha backesi*	-29.428944	-50.392000	Brazil
Leal-Zanchet et al (2012)	-	São Francisco de Paula/RS	sp 110	*Pasipha brevilineata*	-29.428944	-50.392000	Brazil
Lemos & Leal-Zanchet (2008)	-	São Francisco de Paula/RS	sp 111	*Luteostriata pseudoceciliae*	-29.428944	-50.392000	Brazil
du Bois Reymond-Marcus (1951)	-	Brusque/SC	sp 112	*Choeradoplana langi*	-27.111325	-48.895427	Brazil
Graff (1899)	-	Blumenau/SC	sp 112	*Choeradoplana langi*	-27.05386	-49.08606	Brazil
F3590	External, F and AC	Saint-Hilaire	sp 113	*Cratera* sp. 3	-25.469604	-48.813739	Brazil
Hyman (1955)	-	São Bento do Sul/ SC	sp 114	*Obama catharina*	-26.23	-49.40	Brazil
Rossi et al (2014)	-	Cambará do Sul/ RS	sp 115	*Cratera steffeni*	-29.179104	-50.080631	Brazil
F7267	External	PN São Joaquim	sp 116	*Cratera ochra*	-28.157565	-49.638002	Brazil
Rossi et al (2016)	-	São Francisco de Paula/RS	sp 116	*Cratera ochra*	-29.428944	-50.392000	Brazil
Rossi et al (2016)	-	Praia Grande/SC	sp 117	*Obama maculipunctata*	-29.198086	-50.026672	Brazil

Rossi et al (2016)	-	São Francisco de Paula/RS	sp 117	*Obama maculipunctata*	-29.428944	-50.392000	Brazil
Rossi & Leal-Zanchet (2017)	-	General Carneiro/ PR	sp 118	*Cratera nigrimarginata*	-26.44	-51.31	Brazil
Rossi & Leal-Zanchet (2017)	-	Três Barras/SC	sp 119	*Cratera cryptolineata*	-26.19	-50.33	Brazil
Rossi & Leal-Zanchet (2017)	-	Três Barras/SC	sp 120	*Cratera aureomaculata*	-26.19	-50.33	Brazil
Schirch (1929)	-	Resende/RJ	sp 121	*Obama itatiayana*	-22.38	-44.68	Brazil
Graff (1899)	-	Morro Reuter/RS	sp 122	*Notogynaphallia octostriata*	-29.53	-51.07	Brazil
Schultze & Müller (1857)	-	Blumenau/SC	sp 122	*Notogynaphallia octostriata*	-27.05386	-49.08606	Brazil
Carbayo et al (2017)	-	Santa Teresa/ES	sp 123	*Choeradoplana albonigra*	-19.90	-40.54	Brazil
Carbayo et al (2017)	-	Santa Maria Madalena/RJ	sp 123	*Choeradoplana albonigra*	-21.90	-41.95	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 123	*Choeradoplana albonigra*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 124	*Pasipha biseminalis*	-22.439089	-42.994351	Brazil
F3582	External and all internal	Saint-Hilaire	sp 125	*Cratera* sp. 2	-25.469604	-48.813739	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 126	*Pasipha caeruleonigra*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 127	*Geoplana goetschi*	-22.439089	-42.994351	Brazil
F1637	External, F and AC	Saint-Hilaire	sp 128	*Obama* sp. 5	-25.469604	-48.813739	Brazil
Riester (1938)	-	Nova Lima/MG	sp 129	*Pasipha velutina*	-20.02	-43.91	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 130	*Geoplana incognita*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 131	*Obama eudoxiae*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 132	*Obama dictyonota*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Nova Lima/MG	sp 133	*Geoplana notophthalma*	-20.02	-43.91	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 133	*Geoplana notophthalma*	-22.439089	-42.994351	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 134	*Obama eudoximariae*	-22.500057	-42.997365	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 135	*Obama riesteri*	-22.500057	-42.997365	Brazil
Graff (1899)	-	Rio de Janeiro/RJ	sp 136	*Obama fryi*	-22.975852	-43.292230	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 136	*Obama fryi*	-22.500057	-42.997365	Brazil
Negrete & Brusa (2014)	-	San Antonio/Arg	sp 137	*Choeradoplana crassiphalla*	-26.132969	-53.716113	Argentina
F2694	External, A1, F and AC	PE Intervales	sp 138	*Cratera* sp. 1	-24.269387	-48.405467	Brazil
Negrete & Brusa (2016)	-	San Antonio/Arg	sp 139	*Cratera viridimaculata*	-26.132969	-53.716113	Argentina
Negrete et al (2014)	-	San Antonio/Arg	sp 140	*Supramontana argentina*	-25.638105	-54.324086	Argentina
Negrete et al (2014)	-	San Antonio/Arg	sp 140	*Supramontana argentina*	-26.132969	-53.716113	Argentina
Negrete & Brusa (2016)	-	San Antonio/Arg	sp 141	*Pasipha atla*	-26.132969	-53.716113	Argentina
Negrete & Brusa (2016)	-	San Antonio/Arg	sp 142	*Pasipha johnsoni*	-26.132969	-53.716113	Argentina
Negrete & Brusa (2016)	-	San Antonio/Arg	sp 143	*Pasipha mbya*	-25.717567	-54.59656	Argentina
Negrete & Brusa (2016)	-	San Antonio/Arg	sp 143	*Pasipha mbya*	-26.132969	-53.716113	Argentina
Carbayo & Froehlich (2012)	-	São Paulo/SP	sp 144	*Choeradoplana banga*	-23.45	-46.63	Brazil
Carbayo et al (2017)	-	Campos do Jordão/SP	sp 144	*Choeradoplana banga*	-22.70	-45.52	Brazil
Carbayo et al (2017)	-	São Francisco de Paula/RS	sp 145	*Choeradoplana benyai*	-29.42	-50.39	Brazil
F3813	External, A1, F and AC	PE Tabuleiro	sp 145	*Choeradoplana benyai*	-27.86	-48.91	Brazil
Carbayo & Froehlich (2012)	-	São José do Barreiro/SP	sp 146	*Choeradoplana bocaina*	-22.75	-44.62	Brazil
Carbayo & Froehlich (2012)	-	Ribeirão Grande/ SP	sp 147	*Choeradoplana gladismariae*	-24.26	-48.40	Brazil
Carbayo et al (2016)	-	Santo André/SP	sp 148	*Obama otavioi*	-23.77637	-46.31195	Brazil

Carbayo & Almeida (2015)	-	Santa Maria Madalena/RJ	sp 149	*Cratera cuarassu*	-21.87	-41.91	Brazil
Carbayo & Almeida (2015)	-	Teresópolis/RJ	sp 150	*Cratera anamariae*	-22.500057	-42.997365	Brazil
Almeida et al (2012)	-	Teresópolis/RJ	sp 151	*Paraba piriana*	-22.45528	-42.99750	Brazil
Almeida et al (2012)	-	Paulo Lopes/SC	sp 152	*Paraba tingauna*	-27.865111	-48.919389	Brazil
Almeida et al (2012)	-	Paulo Lopes/SC	sp 152	*Paraba tingauna*	-27.94944	-48.79556	Brazil
Carbayo et al (2013)	-	São Francisco de Paula/RS	sp 153	*Cephaloflexa araucariana*	-29.42736	-50.39838	Brazil
Carbayo et al (2013)	-	Matinhos/PR	sp 154	*Cratera picuia*	-25.76437	-48.62266	Brazil
Amaral et al (2014)	-	Salvador do Sul/ RS	sp 155	*Imbira guaiana*	-29.442428	-51.502151	Brazil
F7325	External	PN São Joaquim	sp 155	*Imbira guaiana*	-28.039273	-49.614560	Brazil
Leal-Zanchet & Carbayo (2001)	-	São Francisco de Paula/RS	sp 155	*Imbira guaiana*	-29.41666	-50.38333	Brazil
Graff (1899)	-	Blumenau/SC	sp 156	*Choeradoplana spatulata*	-27.04836	-49.09200	Brazil
Graff (1899)	-	Blumenau/SC	sp 157	*Rhynchodemus blainvillei*	-27.04836	-49.09200	Brazil
Graff (1899)	-	Blumenau/SC	sp 158	*Anisorhynchodemus pellucidus*	-27.04836	-49.09200	Brazil
Graff (1899)	-	Joinville/SC	sp 159	*Choeradoplana ehrenreichi*	-26.28	-48.86	Brazil
Graff (1899)	-	Nova Friburgo/RJ	sp 160	*Obama argus*	-22.26	-42.56	Brazil
Carbayo et al (2018)	-	São Francisco de Paula/RS	sp 161	*Choeradoplana iheringi*	-29.427361	-50.398389	Brazil
Carbayo et al (2018)	-	Parobé/RS	sp 161	*Choeradoplana iheringi*	-29.63	-50.87	Brazil
Graff (1899)	-	Taquara/RS	sp 161	*Choeradoplana iheringi*	-29.659801	-50.779542	Brazil
Almeida et al (2018)	-	Teresópolis/RJ	sp 162	*Choeradoplana pucupucu*	-22.439089	-42.994351	Brazil
Almeida et al (2018)	-	São José do Barreiro/SP	sp 162	*Choeradoplana pucupucu*	-22.74	-44.61	Brazil
Almeida et al (2018)	-	Ribeirão Pires/SP	sp 162	*Choeradoplana pucupucu*	-23.701329	-46.39	Brazil
Almeida et al (2018)	-	São Bonifácio/SC	sp 163	*Choeradoplana abaiba*	-27.84	-48.92	Brazil
Almeida et al (2018)	-	Paulo Lopes/SC	sp 163	*Choeradoplana abaiba*	-27.947500	-48.751111	Brazil
Almeida et al (2018)	-	Paulo Lopes/SC	sp 163	*Choeradoplana abaiba*	-27.961389	-48.758333	Brazil
Almeida et al (2018)	-	Santa Maria Madalena/RJ	sp 164	*Choeradoplana agua*	-21.876667	-41.919722	Brazil
Álvarez-Presas et al (2015)	-	São Paulo/SP	sp 165	*Obama anthropophila*	-23.50	-46.54	Brazil
Álvarez-Presas et al (2015)	-	Blumenau/SC	sp 165	*Obama anthropophila*	-27.05386	-49.08606	Brazil
Álvarez-Presas et al (2015)	-	São Bonifácio/SC	sp 165	*Obama anthropophila*	-27.84	-48.92	Brazil
Álvarez-Presas et al (2015)	-	São Francisco de Paula/RS	sp 165	*Obama anthropophila*	-29.42964	-50.39783	Brazil
Álvarez-Presas et al (2015)	-	Salvador do Sul/ RS	sp 165	*Obama anthropophila*	-29.440556	-51.507778	Brazil
Álvarez-Presas et al (2015)	-	Ivoti/RS	sp 165	*Obama anthropophila*	-29.610000	-51.163611	Brazil
Álvarez-Presas et al (2015)	-	Taquara/RS	sp 165	*Obama anthropophila*	-29.659801	-50.779542	Brazil
Álvarez-Presas et al (2015)	-	Portão/RS	sp 165	*Obama anthropophila*	-29.69	-51.27	Brazil
Álvarez-Presas et al (2015)	-	Novo Hamburgo/ RS	sp 165	*Obama anthropophila*	-29.72	-51.12	Brazil
Carbayo et al (2016)	-	Ribeirão Grande/ SP	sp 165	*Obama anthropophila*	-24.26	-48.40	Brazil
Carbayo et al (2016)	-	Paulo Lopes/SC	sp 165	*Obama anthropophila*	-27.84278	-48.92583	Brazil
F1414	External, F and AC	PN Itajaí	sp 165	*Obama anthropophila*	-27.04836	-49.09206	Brazil
F2647	External and AC	PE Intervales	sp 165	*Obama anthropophila*	-24.269387	-48.405467	Brazil
F3346	External, F and AC	PE Tabuleiro	sp 165	*Obama anthropophila*	-27.840735	-48.924866	Brazil
F3360	External	FLONA-SFP	sp 165	*Obama anthropophila*	-29.428944	-50.392000	Brazil
Carbayo et al (2016)	-	Santa Maria/RS	sp 166	*Obama decidualis*	-29.74167	-53.84417	Brazil
Carbayo et al (2016)	-	Paulo Lopes/SC	sp 167	*Obama nungara*	-27.84278	-48.92583	Brazil

F7439	External	PN São Joaquim	sp 167	*Obama nungara*	-27.959777	-49.482612	Brazil
Almeida et al (2018)	-	São Sebastião/SP	sp 168	*Geoplana boraceia*	-23.75203	-45.631027	Brazil
Almeida et al (2018)	-	Salesópolis/SP	sp 168	*Geoplana boraceia*	-23.75203	-45.631027	Brazil
Almeida et al (2018)	-	Morretes/PR	sp 169	*Geoplana chita*	-25.469604	-48.813739	Brazil
Almeida et al (2018)	-	Matinhos/PR	sp 170	*Geoplana cambara*	-25.71	-48.62	Brazil
Almeida et al (2018)	-	Matinhos/PR	sp 170	*Geoplana cambara*	-25.76437	-48.62266	Brazil
Almeida et al (2018)	-	Cananeia/SP	sp 171	*Geoplana cananeia*	-25.091235	-47.928957	Brazil
Almeida et al (2018)	-	Caraguatatuba/SP	sp 172	*Geoplana caraguatatuba*	-23.594012	-45.429672	Brazil
Almeida et al (2018)	-	Santana de Parnaiba/SP	sp 173	*Geoplana ibiuna*	-23.449229	-47.012175	Brazil
Almeida et al (2018)	-	Ibiúna/SP	sp 173	*Geoplana ibiuna*	-23.93	-47.19	Brazil
Almeida et al (2018)	-	Ribeirão Grande/ SP	sp 174	*Geoplana iporanga*	-24.269387	-48.405467	Brazil
F3166	External and all internal	PE Intervales	sp 174	*Geoplana iporanga*	-24.269387	-48.405467	Brazil
Almeida et al (2018)	-	Mogi das Cruzes/ SP	sp 175	*Geoplana mogi*	-23.451536	-46.227993	Brazil
Almeida et al (2018)	-	São Paulo/SP	sp 175	*Geoplana mogi*	-23.570942	-46.693776	Brazil
Almeida et al (2018)	-	Santo André/SP	sp 176	*Geoplana paranapiacaba*	-23.77746	-46.30145	Brazil
Almeida et al (2018)	-	São Paulo/SP	sp 177	*Geoplana piratininga*	-23.490918	-46.516424	Brazil
Darwin (1844)	-	Rio de Janeiro/RJ	sp 178	*Geoplana vaginuloides*	-22.93707	-43.46098	Brazil
Riester (1938)	-	Teresópolis/RJ	sp 178	*Geoplana vaginuloides*	-22.439089	-42.994351	Brazil
Almeida et al (2018)	-	Nova Iguaçu/RJ	sp 179	*Geoplana apua*	-22.71	-43.56	Brazil
Almeida et al (2018)	-	Santa Teresa/ES	sp 180	*Issoca assanga*	-19.88740	-40.54319	Brazil
Almeida et al (2018)	-	Santa Maria Madalena/RJ	sp 180	*Issoca assanga*	-21.87694	-41.92583	Brazil
F2751	External, F and AC	PE Intervales	sp 181	*Choeradoplana* sp. 8	-24.269387	-48.405467	Brazil
F2638	External and AC	PE Intervales	sp 182	*Geoplana* sp. 9	-24.269387	-48.405467	Brazil
F3804	External and AC	PE Intervales	sp 183	Geoplaninae 7	-24.269387	-48.405467	Brazil
F3764	External, A1, F and AC	PE Intervales	sp 184	*Issoca* sp. 2	-24.269387	-48.405467	Brazil
F3758	External and AC	PE Intervales	sp 185	*Luteostriata* sp. 1	-24.269387	-48.405467	Brazil
F1715	External, F and AC	PN Saint Hilaire	sp 186	*Obama* sp. 8	-25.469604	-48.813739	Brazil
F3099	External and AC	PE Intervales	sp 186	*Obama* sp. 8	-24.269387	-48.405467	Brazil
F3760	External and AC	PE Intervales	sp 187	*Obama* sp. 17	-24.269387	-48.405467	Brazil
F3754c	External and AC	PE Intervales	sp 188	*Obama* sp. 24	-24.269387	-48.405467	Brazil
F3768	External and AC	PE Intervales	sp 189	*Paraba* sp. 3	-24.269387	-48.405467	Brazil
F2692	External , F and AC	PE Intervales	sp 190	*Paraba* sp. 6	-24.269387	-48.405467	Brazil
F3754d	External, F and AC	PE Intervales	sp 191	*Paraba* sp. 9	-24.269387	-48.405467	Brazil
F3102	External, F and AC	PE Intervales	sp 192	*Pasipha* sp. 8	-24.269387	-48.405467	Brazil
F3239	External, A1, F and AC	PE Tabuleiro	sp 192	*Pasipha* sp. 8	-27.840735	-48.924866	Brazil
F3265	External	PE Tabuleiro	sp 192	*Pasipha* sp. 8	-27.994964	-48.759313	Brazil
F6511	External	Alfredo Wagner/ SC	sp 192	*Pasipha* sp. 8	-27.61727	-49.35075	Brazil
F7416	External	PN São Joaquim	sp 192	*Pasipha* sp. 8	-28.161997	-49.627107	Brazil
F3482	External and all internal	FLONA-SFP	sp 193	*Pasipha* sp. 11	-29.428944	-50.392000	Brazil
F3796	External, F and AC	PE Intervales	sp 193	*Pasipha* sp. 11	-24.269387	-48.405467	Brazil
F3115	External	PE Intervales	sp 194	*Xerapoa* sp. 1	-24.269387	-48.405467	Brazil

	and all internal						
F7438	External and all internal	PN São Joaquim	sp 194	*Xerapoa* sp. 1	-27.960057	-49.482761	Brazil
F3090	External and AC	PE Intervales	sp 195	*Xerapoa* sp. 2	-24.269387	-48.405467	Brazil
F3378	External, F and AC	FLONA-SFP	sp 196	*Xerapoa* sp. 4	-29.43	-50.37	Brazil
F3417	External and all internal	FLONA-SFP	sp 197	*Choeradoplana* sp. 1	-29.436278	-50.373694	Brazil
F3418	External and F	FLONA-SFP	sp 198	*Imbira* sp. 1	-29.436278	-50.373694	Brazil
F3251	External	PE Tabuleiro	sp 198	*Imbira* sp. 1	-27.94	-48.79	Brazil
F3388	External, F and AC	FLONA-SFP	sp 199	*Pasipha* sp. 2	-29.427361	-50.398389	Brazil
F3439	External	FLONA-SFP	sp 200	Rhynchodeminae sp. 2	-29.42	-50.39	Brazil
F3395	External, A1, F and AC	FLONA-SFP	sp 201	*Paraba* sp. 2	-29.427361	-50.398389	Brazil
F3468	External, F and AC	FLONA-SFP	sp 202	*Geoplana* sp. 1	-29.42	-50.39	Brazil
F7307	External, A1 and AC	PN São Joaquim	sp 273	*Geoplana* sp. 5	-28.038422	-49.613814	Brazil
F3383	External and F	FLONA-SFP	sp 203	*Geoplana* sp. 6	-29.42	-50.39	Brazil
F3472	External, F and AC	FLONA-SFP	sp 204	*Pasipha* sp. 6	-29.42	-50.39	Brazil
F3483	External and AC	FLONA-SFP	sp 205	*Pasipha* sp. 5	-29.42	-50.39	Brazil
F3394	External, A1, F and AC	FLONA-SFP	sp 206	*Geoplana* sp. 7	-29.42	-50.39	Brazil
Lemos et al., 2014	-	São Francisco de Paula/RS	sp 207	*Choeradoplana minima*	-29.42	-50.39	Brazil
F0406	External and AC	FLONA-SFP	sp 208	*Matuxia tymbyra*	-29.42	-50.39	Brazil
F3425	External, A1, F and AC	FLONA-SFP	sp 209	*Paraba* sp. 1	-29.42	-50.39	Brazil
F7423	External, A1 and AC	PN São Joaquim	sp 210	*Barreirana* sp. 1	-28.161702	-49.628062	Brazil
F7273	External and AC	PN São Joaquim	sp 211	*Choeradoplana* sp. 3	-28.282715	-49.556282	Brazil
F7381	External	PN São Joaquim	sp 211	*Choeradoplana* sp. 3	-28.236262	-49.498931	Brazil
F7262	External, F and AC	PN São Joaquim	sp 212	*Choeradoplana* sp. 5	-28.162037	-49.627140	Brazil
F7292	External, F and AC	PN São Joaquim	sp 213	*Choeradoplana* sp. 9	-28.038422	-49.613814	Brazil
F6537	External and AC	Alfredo Wagner/ SC	sp 214	*Choeradoplana* sp. 7	-27.61727	-49.35075	Brazil
F7419	External and AC	PN São Joaquim	sp 215	*Luteostriata* sp. 3	-28.161771	-49.627752	Brazil
F7413	External and AC	PN São Joaquim	sp 216	*Notogynaphallia* sp. 3	-28.161876	-49.627519	Brazil
F7241	External, A1 and AC	PN São Joaquim	sp 217	*Obama* sp. 9	-28.140017	-49.629717	Brazil
F7240	External, A1 and AC	PN São Joaquim	sp 218	*Obama* sp. 10	-28.140421	-49.627143	Brazil
F7318	External, A1 and AC	PN São Joaquim	sp 219	*Obama* sp. 11	-28.038786	-49.614039	Brazil
F7389	External, A1 and	PN São Joaquim	sp 220	*Obama* sp. 13	-28.235706	-49.498816	Brazil

	AC						
F7378	External, A1 and AC	PN São Joaquim	sp 221	*Obama* sp. 16	-28.235617	-49.498897	Brazil
F7294	External	PN São Joaquim	sp 222	*Obama* sp. 17	-28.038956	-49.614243	Brazil
F7424	External, A1, F and AC	PN São Joaquim	sp 223	*Obama* sp. 20	-28.161997	-49.627107	Brazil
F7352	External, A1 and AC	PN São Joaquim	sp 224	*Obama* sp. 22	-28.038432	-49.613820	Brazil
F7362	External, A1 and AC	PN São Joaquim	sp 225	*Obama* sp. 21	-28.038432	-49.613820	Brazil
F7385	External	PN São Joaquim	sp 226	*Obama* sp. 7	-28.235617	-49.498897	Brazil
F3859	External, A1, F and AC	PE Tabuleiro	sp 226	*Obama* sp. 7	-27.840735	-48.924866	Brazil
F7373	External	PN São Joaquim	sp 227	*Paraba* sp. 4	-28.162100	-49.626466	Brazil
F7272	External, A1, F and AC	PN São Joaquim	sp 228	*Paraba* sp. 8	-28.275805	-49.549801	Brazil
F7315	External, A1 and AC	PN São Joaquim	sp 229	*Pasipha* sp. 1	-28.038422	-49.613814	Brazil
F7418	External, A1, F and AC	PN São Joaquim	sp 230	*Pasipha* sp. 3	-28.161958	-49.627265	Brazil
F7343	External	PN São Joaquim	sp 231	*Pasipha* sp. 4	-28.040082	-49.615061	Brazil
F7416	External	PN São Joaquim	sp 232	*Pasipha* sp. 9	-28.161997	-49.627107	Brazil
F7476	External	PN São Joaquim	sp 233	*Pasipha* sp. 12	-27.960810	-49.483000	Brazil
F7248	External, A1, F and AC	PN São Joaquim	sp 234	Geoplaninae 9	-28.14187	-49.63534	Brazil
F7268	External and AC	PN São Joaquim	sp 235	Geoplaninae 2	-28.157942	-49.638496	Brazil
F7486	External, F and AC	PN São Joaquim	sp 236	Geoplaninae 10	-27.961773	-49.483299	Brazil
F7363	External, A1, F and AC	PN São Joaquim	sp 237	Geoplaninae 12	-28.038610	-49.613914	Brazil
F7338	External, A1 and AC	PN São Joaquim	sp 238	Geoplaninae 13	-28.039749	-49.614906	Brazil
F7322	External, F and AC	PN São Joaquim	sp 239	*Xerapoa* sp. 3	-28.039273	-49.614560	Brazil
F7316	External, F and AC	PN São Joaquim	sp 240	*Xerapoa* sp. 5	-28.040082	-49.615061	Brazil
F3352	External, A1, f and AC	PE Tabuleiro	sp 241	Geoplaninae 1	-27.86	-48.91	Brazil
F3228	External and all internal	PE Tabuleiro	sp 242	*Obama* sp. 1	-27.840735	-48.924866	Brazil
F3238	External and all internal	PE Tabuleiro	sp 243	*Obama* sp. 2	-27.84	-48.92	Brazil
F3911	External, A1, F and AC	PE Tabuleiro	sp 244	*Choeradoplana* sp. 2	-27.94	-48.79	Brazil
F3186	External and F	PE Tabuleiro	sp 245	*Choeradoplana* sp. 4	-27.94	-48.79	Brazil
F3226	External and all internal	PE Tabuleiro	sp 246	*Choeradoplana tristriata*	-27.94	-48.79	Brazil
F3340	External, F and AC	PE Tabuleiro	sp 247	*Obama* sp. 3	-27.840735	-48.924866	Brazil
F3918	External	PE Tabuleiro	sp 248	Geoplaninae 3	-27.94	-48.79	Brazil

	and all internal						
F3823	External and all internal	PE Tabuleiro	sp 249	Geoplaninae 5	-27.84	-48.92	Brazil
F3241	External, A1, F and AC	PE Tabuleiro	sp 250	Geoplaninae 8	-27.94	-48.79	Brazil
F3904	External, A1, F and AC	PE Tabuleiro	sp 251	*Supramontana* sp. 1	-27.84	-48.92	Brazil
F3289	External, A1, F and AC	PE Tabuleiro	sp 252	*Luteostriata* sp. 2	-27.840735	-48.924866	Brazil
F3229	External, A1 and AC	PE Tabuleiro	sp 253	*Notogynaphallia* sp. 2	-27.840735	-48.924866	Brazil
F3888	External, A1, F and AC	PE Tabuleiro	sp 254	*Notogynaphallia* sp. 4	-27.840735	-48.924866	Brazil
F3280	External, A1, F and AC	PE Tabuleiro	sp 255	*Obama* sp. 6	-27.840735	-48.924866	Brazil
F6530	External	Alfredo Wagner/ SC	sp 255	*Obama* sp. 6	-27.61727	-49.35075	Brazil
F3183	External and AC	PE Tabuleiro	sp 256	*Obama* sp. 19	-27.94	-48.79	Brazil
F3890	External	PE Tabuleiro	Sp 257	*Pasipha* sp. 10	-27.94	-48.79	Brazil
F6541	External	Alfredo Wagner/ SC	Sp 257	*Pasipha* sp. 10	-27.61727	-49.35075	Brazil
F3185	Externala nd all internal	PE Tabuleiro	Sp 258	Geoplaninae 11	-27.94	-48.79	Brazil
F3876	External, A1 and AC	PE Tabuleiro	Sp 259	Geoplaninae 15	-27.840735	-48.924866	Brazil
F4628	Externala nd AC	PNItajai	Sp 260	*Cratera* sp. 4	-27.05386	-49.08606	Brazil
F1415	External, F and AC	PN Itajaí	Sp 261	Geoplaninae 4	-27.05306	-49.08528	Brazil
F4627	Externala nd AC	PNItajai	Sp 262	Geoplaninae 14	-27.05386	-49.08606	Brazil
F1726	External and all internal	Saint-Hilaire	Sp 263	*Choeradoplana* sp. 6	-25.469604	-48.813739	Brazil
F1707	External, A1 and F	Saint-Hilaire	Sp 264	*Geoplana* sp. 3	-25.469604	-48.813739	Brazil
F3586	External and all internal	Saint-Hilaire	Sp 265	*Geoplana* sp. 8	-25.469604	-48.813739	Brazil
F1638	External, A1, F and AC	Saint-Hilaire	Sp 266	*Obama* sp. 12	-25.71	-48.62	Brazil
F1657	External, A1, F and AC	Saint-Hilaire	Sp 267	Geoplaninae 6	-25.469604	-48.813739	Brazil
Carbayo et al (2013)	-	São Paulo/SP	Sp 268	*Geoplana* sp. 2	-23.453148	-46.634488	Brazil
CG Froehlich (1956a)	-	Ubatuba/SP	Sp 269	*Cratera* sp. 6	-23.423381	-45.083399	Brazil
Marcus (1951)	-	São Paulo/SP	Sp 270	*Paraba* sp. 5	-23.500212	-46.702310	Brazil

S2 Table. Records of land planarian species from literature excluded from this study and justification for such decision.

Species	Locality	Reference	Why excluded from analyses
Cephaloflexa bergi	Teresópolis/RJ	Froehlich, 1956a	Missing information
Cephaloflexa bergi		Marcus, 1951	There are numerous records elsewhere
Cephaloflexa bergi		Riester, 1938	Missing information
Choeradoplana iheringi	São Leopoldo/RS	Froehlich, 1959	See Carbayo et al 2017
Choeradoplana iheringi		Amaral et al., 2014	Misidentification
Choeradoplana iheringi		Froehlich, 1955	
Choeradoplana iheringi		Marcus, 1951	See Carbayo et al., 2017
Choeradoplana iheringi		Baptista et al., 2006	See Carbayo et al., 2017
Choeradoplana iheringi		Fick et al., 2006	Complex case
Choeradoplana iheringi		Leal-Zanchet et al., 2011	Complex case
Choeradoplana iheringi		Riester, 1938	Outdated
Choeradoplana langi	Paraguay, Argentina	du Bois-Reymenond Marcus, 1953	Doubtful record
Geoplana brasiliensis		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana distincta		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana elegans	Rio de Janeiro/RJ	Graff, 1899	Identification dubious
Geoplana ferussaci		Graff, 1899	Identification dubious
Geoplana goeldii		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana maximiliani		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana nephelis		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana perspicilata		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana rostrata		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana schultzei		Graff, 1899	Notogynaphallia schultzei
Geoplana tristriata		Graff, 1899	Belongs to genus Pseudogeoplana
Geoplana vaginuloides		Graff, 1899	Outdated
Geoplana chita		Froehlich, 1956b	See Almeida et al., 2018
Geoplana goetschi		Froehlich, 1957	Identification dubious
Geoplana goetschi	Teresópolis/RJ	Froehlich, 1956a	Identification dubious
Geoplana goetschi	Ubatuba/SP	Froehlich, 1956a	Identification dubious
Geoplana leucophryna		Marcus, 1951	Synonym of Obama burmeisteri
Geoplana marginata	Blumenau/SC	Froehlich, 1959	Identification dubious
Geoplana marginata	Curitiba, Caiobá/PR	Froehlich, 1956b	Identification dubious
Geoplana marginata		Froehlich, 1957	Identification dubious
Geoplana marginata		Marcus, 1951	Identification dubious
Geoplana nigrofusca		Graff, 1899	Identification dubious
Geoplana rufiventris		Graff, 1899	Identification dubious
Geoplana vaginuloides		Froehlich, 1957	Misidentification
Geoplana vaginuloides		Marcus, 1951	See Almeida et al., 2018
Geoplana vaginuloides		Riester, 1938	Misidentification

Issoca rezendei	Baia de Pranaguá/PR	Froehlich 1955	Missing information
Luteostriata muelleri	Paranapiacaba/SP, Santo André/SP	Froehlich, 1959	Doubts about conspecificity
Notogynaphallia sexlineata (Riester, 1938)		Riester, 1938	Internal morphology unknown
Obama burmeisteri		Froehlich, 1955b	Locality not mentioned
Obama carreirei		Amaral et al, 2014	Complex case
Paraba gaucha	"According to the collector, a common species at that locality, and also at Pôrto Alegre, capital of the State"	Froehlich, 1959	Evidence lacking
Pseudogeoplana elegans	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana maximiliani	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana nephelis	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana nephelis	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana octostriata	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana olivacea	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana pallida	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana rufiventris	Blumenau/SC	Froehlich, 1959	Dubious identification
Pseudogeoplana tristriata	Blumenau/SC	Froehlich, 1959	Dubious identification

S3 Table. Geographic distribution of the land planarian species and their classification regarding their endemicity level.

Abbreviations: CC, Congruence Core; WS, Widespread; MRE, Maximum Region of Endemism; SSC, South Santa Catarina; NSC, North Santa Catarina; Org: Serra dos Órgãos; PNSJ, Parque Nacional de São Joaquim; SFP, São Francisco de Paula; SMSP, Serra do Mar de São Paulo; SSP, Southern São Paulo; PR, Paraná; MIS, Misiones; POA, Porto Alegre; x, other cells.

Scientific name	**AoE**	**Endemicity level**	**Single Record (SR)**
Geoplaninae 1	SSC	CC	+
Anisorhynchodemus pellucidus (Graff, 1899)	NSC	CC	+
Barreirana barreirana (Riester, 1938)	Org/Ubatuba	WS	
Barreirana zebroides (Riester, 1938)	Org	CC	+
Barreirana sp. 1	PNSJ	CC	+
Obama sp. 1	SSC	CC	+
Paraba sp. 10	SSC	CC	+
Cephaloflexa araucariana Carbayo & Leal-Zanchet, 2003	SFP	CC	+
Cephaloflexa bergi Graff, 1899	Org, SMSP, NSC, SSC, SSP, PR, x	WS	
Cephaloflexa nataliae (Froehlich, 1959)	NSC	CC	+
Choeradoplana sp. 1	SFP	CC	+
Choeradoplana abaiba Carbayo et al., 2018	SSC	CC	
Choeradoplana sp. 2	SSC	CC	+
Choeradoplana agua Carbayo et al., 2018	SMMadalena	CC	+
Choeradoplana albonigra (Riester, 1938)	Org, SMMadalena	WS	
Choeradoplana banga Carbayo & Froehlich, 2012	SMSP	MRE	
Choeradoplana benyai Lemos & Leal-Zanchet, 2014	SSC, SFP	WS	
Choeradoplana bilix Marcus, 1951	x		+
Choeradoplana bocaina Carbayo & Froehlich, 2012	Bocaina	CC	+
Choeradoplana sp. 3	PNSJ	CC	
Choeradoplana catua Froehlich, 1954	Org	CC	+
Choeradoplana sp. 4	SSC	CC	+
Choeradoplana crassiphalla Negrete & Brusa, 2012	MIS	CC	+
Choeradoplana ehrenreichi Graff, 1899	x		+
Choeradoplana gladismariae Carbayo & Froehlich, 2012	SSP	CC	+
Choeradoplana iheringi Graff, 1899	SFP, POA	WS	
Choeradoplana langi (Dendy, 1894)	NSC	CC	
Choeradoplana sp. 5	PNSJ	CC	+
Choeradoplana sp. 6	PR	CC	+
Choeradoplana marthae Froehlich, 1954	SMSP	MRE	
Choeradoplana minima Lemos & Leal-Zanchet, 2014	SFP	CC	+

Choeradoplana sp. 7	SSC	MRE-CC	+
Choeradoplana pucupucu Carbayo et al., 2018	SMSP, Org	WS	
Choeradoplana sp. 8	SSP	CC	+
Choeradoplana spatulata Graff, 1899	NSC	CC	+
Choeradoplana sp. 9	PNSJ	CC	+
Pseudogeoplana tristriata (Schultze & Müller, 1857)	SSC	CC	+
Cratera anamariae Carbayo, 2015	Org	CC	+
Cratera arucuia Lago-Barcia & Carbayo, 2018	SSP	CC	+
Cratera aureomaculata Rossi & Leal-Zanchet, 2017	Três Barras	CC	+
Cratera crioula (Froehlich, 1955)	SMSP	CC	+
Cratera cryptolineata Rossi & Leal-Zanchet, 2017	Três Barras	CC	+
Cratera cuarassu Carbayo & Almeida, 2015	SMMadalena	CC	+
Cratera hina (Marcus, 1951)	SMSP	CC	+
Cratera joia (Froehlich, 1956)	PR	CC	+
Cratera sp. 1	SSP	CC	+
Cratera sp. 2	PR	CC	+
Cratera sp. 3	PR	CC	+
Cratera sp. 4	NSC	CC	+
Cratera sp. 5	PNSJ	CC	+
Cratera nigrimarginata Rossi & Leal-Zanchet, 2017	x		+
Cratera sp. 6	Ubatuba	CC	+
Cratera ochra Rossi et al., 2016	SFP, PNSJ	MRE	
Cratera picuia Lago-Barcia & Carbayo, 2018	Matinhos	CC	+
Cratera pseudovaginuloides (Riester, 1938)	Org	CC	+
Cratera steffeni Rossi et al., 2014	SFP	CC	+
Cratera tamoia (Froehlich, 1955)	Org	CC	
Cratera taxiarcha (Marcus, 1951)	SMSP	CC	+
Cratera viridimaculata Negrete & Brusa, 2016	MIS	CC	+
Cratera yara (Froehlich, 1955)	Org	CC	+
Geoplaninae 2	PNSJ	CC	+
Obama sp. 3	SSC	CC	+
Geobia subterranea (Schultze & Müller, 1857)	ORG, SMSP, SCN, POA, PR, x	WS	
Geoplaninae 16	SFP	CC	+
Geoplana apua Almeida & Carbayo, 2018	Org	MRE?	+
Imbira sp. 2	SMSP	CC	+
Geoplana boraceia Almeida & Carbayo, 2018	x		+
Geoplana cambara Almeida & Carbayo, 2018	Matinhos	CC	
Geoplana cananeia Almeida & Carbayo, 2018	x		+
Geoplana caraguatatuba Almeida & Carbayo, 2018	x		+
Geoplana carrierei sensu Marcus, 1951	SMSP, POA	WS	
Geoplana chita Froehlich, 1956	PR	CC	+
Geoplana sp. 1	PR	CC	+
Geoplana chiuna Froehlich, 1955	x		+
Geoplana duca Marcus, 1951	SMSP	CC	+
Geoplana ferussaci sensu Riester, 1938	ORG, SMSP, x	WS	

Geoplana fragai Froehlich, 1955	Org	CC	+
Geoplana goetschi Riester, 1938	Org	CC	+
Geoplana ibiuna Almeida & Carbayo, 2018	x	MRE	
Paraba incognita (Riester, 1938)	Org	CC	+
Geoplana iporanga Almeida & Carbayo, 2018	SSP	CC	+
Geoplana jandira Froehlich, 1955	Org	CC	+
Geoplana mogi Almeida & Carbayo, 2018	SMSP	CC	
Geoplaninae 17	PNSJ	CC	+
Geoplana nigra Froehlich, 1959	POA	CC	+
Geoplana notophthalma Riester, 1938	Org	MRE	
Geoplaninae 18	SFP	CC	+
Geoplana paranapiacaba Almeida & Carbayo, 2018	SMSP	CC	+
Geoplana pavani Marcus, 1951	SMSP	CC	+
Geoplana picta Froehlich, 1956	Ubatuba		+
Geoplana piratininga Almeida & Carbayo, 2018	SMSP	CC	+
Geoplaninae 19	SFP	CC	+
Geoplana pulchella (Schultze & Müller, 1857)	NSC, SSC	WS	
Geoplana quagga Marcus, 1951	ORG, SMSP, NSC	WS	
Geoplana regia Froehlich, 1954	x		+
Geoplana sp. 2	PR	CC	+
Geoplana toriba Froehlich, 1957	SSP	MRE	+
Geoplana sp. 3	SSP	CC	+
Geoplana vaginuloides (Darwin, 1844)	Org	CC	+
Geoplaninae 3	SSC	CC	+
Geoplaninae 4	NSC	CC	+
Geoplaninae 5	SSC	CC	+
Geoplaninae 6	PR	CC	+
Geoplaninae 7	SSP	CC	+
Geoplaninae 8	SSC	CC	+
Imbira flavonigra Amaral & Leal-Zanchet, 2018	SFP	CC	+
Imbira sp. 1	SFP, SSC	WS	
Imbira guaiana (Leal-Zanchet & Carbayo, 2001)	SFP, POA	WS	
Imbira marcusi Carbayo et al., 2013	SMSP, SSP, PR, x	WS	
Imbira negrita Negrete & Brusa, 2017	MIS	MRE	+
Issoca assanga Araujo & Carbayo, 2018	SMMadalena	MRE	
Issoca jandaia (Froehlich, 1954)	SMSP, SSP	WS	
Issoca piranga (Froehlich, 1954)	Org	CC	+
Issoca potyra (Froehlich, 1957)	SSP	MRE	
Issoca rezendei (Schirch, 1929)	ORG, SMSP, SCN, PR, x	WS	
Issoca sp. 2	SSP	CC	+
Luteostriata abundans (Graff, 1899)	POA	CC	
Luteostriata arturi (Lemos & Leal-Zanchet, 2008)	SFP	CC	
Luteostriata caissara (Froehlich, 1954)	SMSP, Org	WS	
Luteostriata ceciliae (Froehlich & Leal-Zanchet, 2003)	SFP	CC	

Luteostriata sp. 1	SSP	CC	+
Luteostriata ernesti (Leal-Zanchet & Froehlich, 2006)	SMSP, SCS, POA, x	WS	
Luteostriata sp. 2	SSC	CC	+
Luteostriata fita (Froehlich, 1959)	NSC	CC	+
Luteostriata sp. 3	PNSJ	CC	+
Luteostriata graffi (Leal-Zanchet & Froehlich, 2006)	SFP, POA, Flori	WS	
Luteostriata sp. 4	Matinhos	CC	+
Luteostriata muelleri (Diesing, 1861)	NSC, SSC	WS	
Luteostriata pseudoceciliae (Lemos & Leal-Zanchet, 2008)	SFP	CC	+
Matuxia tymbyra Rossi & Leal-Zanchet, 2019	SFP	CC	+
Matuxia matuta (Froehlich, 1954)	Org, SMMadalena	WS	
Matuxia tuxaua (Froehlich, 1954)	SMSP, Org	WS	
Notogynaphallia atra (Schultze & Müller, 1857)	SFP, NSC	WS	
Notogynaphallia mourei (Froehlich, 1956)	PR	MRE	
Notogynaphallia sp. 1	NSC, POA	WS	
Notogynaphallia parca (Froehlich, 1954)	SMSP	CC	+
Notogynaphallia sp. 2	SSC	CC	+
Notogynaphallia plumbea (Froehlich, 1956)	SMSP, SCS, SSP, PR, x	WS	
Notogynaphallia sp. 3	PNSJ	CC	+
Notogynaphallia sexstriata (Graff, 1899)	ORG, SMSP, SCN, POA, PR, x	WS	
Notogynaphallia sp. 4	SSC	CC	+
Obama sp. 5	PR	CC	+
Obama anthropophila Amaral et al., 2015	SCN, SCS, SSP, SFP, POA, x	WS	
Obama apeva (Froehlich, 1959)	NSC, SSC	WS	
Obama applanata (Graff, 1899)	Org	CC	+
Obama argus (Graff, 1899)	Org	MRE	+
Obama assu (Froehlich, 1959)	NSC	MRE-CC	
Obama baptistae (Leal-Zanchet & Oliveira, 2012)	Smaria	CC	+
Obama braunsi (Graff, 1899)	SMSP	MRE	
Obama burmeisteri (Schultze & Müller, 1857)	ORG, SMSP, SCN, POA, x	WS	
Obama carbayoi (Oliveira & Leal-Zanchet, 2012)	Derrubadas	CC	+
Obama carinata (Riester, 1938)	SMSP, SSP	WS	
Obama catharina (Hyman, 1957)	x		+
Obama sp. 6	SSC	MRE-CC	
Obama sp. 7	SSC	MRE	
Obama decidualis Amaral & Leal-Zanchet, 2015	Smaria	CC	+
Obama dictyonota (Riester, 1938)	Org	CC	+
Obama divae (Marcus, 1951)	SMSP, SSP	WS	
Obama eudoxiae (Ogren & Kawakatsu, 1990)	Org	CC	+
Obama eudoximariae (Ogren & Kawakatsu, 1990)	Org	CC	+
Obama evelinae (Marcus, 1951)	SMSP	MRE	

Obama ferussaci sensu Graff, 1899	PR, SSP	WS	
Obama sp. 9	PNSJ	CC	+
Obama ficki (Amaral & Leal-Zanchet, 2012)	SFP, POA	WS	
Obama fryi (Graff, 1899)	Org	CC	
Obama glieschi (Froehlich, 1959)	Derrubadas	MRE	+
Obama itatiayana (Schirch, 1929)	x		+
Obama josefi (Carbayo & Leal-Zanchet, 2001)	SFP	CC	
Obama ladislavii (Graff, 1899)	SCN, SCS, POA, SFP	WS	
Obama livia (Froehlich, 1954)	SMSP	CC	
Obama maculipunctata (Rossi et al., 2016)	SFP	CC	
Obama sp. 10	PNSJ	CC	+
Obama sp. 11	PNSJ	CC	+
Obama marmorata (Schultze & Müller, 1857)	NSC, SSC	WS	
Obama metzi (Graff, 1899)	SMSP	CC	
Obama sp. 12	Matinhos	CC	+
Obama nungara Carbayo et al., 2016	SSC	MRE-CC	
Obama sp. 13	PNSJ	CC	+
Obama otavioi Carbayo, 2016	SMSP	CC	+
Obama sp. 14	PNSJ	CC	+
Obama poca (Froehlich, 1957)	SMSP	MRE	+
Obama polyophthalma (Graff, 1899)	SCN, POA, PR	WS	
Obama sp. 16	PSNJ	CC	+
Obama sp. 17	SSP	CC	+
Obama riesteri (Froehlich, 1954)	Org	CC	+
Obama sp. 18	PSNJ	CC	+
Obama sp. 19	SSC	CC	+
Obama schubarti (Froehlich, 1957)	SMSP	MRE	
Obama sp. 20	PSNJ	CC	+
Obama sp. 21	PSNJ	CC	+
Obama sp. 2	PSNJ	CC	+
Obama trigueira (Froehlich, 1955)	Org	CC	
Obama sp. 8	SSP	CC	+
Paraba sp. 1	SFP	CC	+
Paraba caapora (Froehlich, 1958)	NSC, SSP	WS	
Paraba cassula (Froehlich, 1955)	Org	CC	+
Paraba franciscana (Leal-Zanchet & Carbayo, 2001)	SFP	CC	
Paraba gaucha (Froehlich, 1959)	POA	CC	
Paraba goettei (Schirch, 1929)	Org	CC	+
Paraba sp. 2	SFP	CC	+
Paraba sp. 3	SSP	CC	+
Paraba sp. 4	PNSJ	CC	+
Paraba multicolor (Graff, 1899)	ORG, SMSP, SCS, POA, SSP, x	WS	
Paraba sp. 5	SMSP	CC	+
Paraba phocaica (Marcus, 1951)	SMSP	CC	+

Paraba piriana (Almeida & Carbayo, 2012)	Org	CC	+
Paraba preta (Riester, 1938)	Org	CC	+
Paraba sp. 6	SSP	CC	+
Paraba rubidolineata (Baptista & Leal-Zanchet, 2005)	SFP, SSC	WS	
Paraba sp. 7	Bocaina		+
Paraba suva (Froehlich, 1959)	NSC	CC	+
Paraba tapira (Froehlich, 1958)	SSP	MRE	
Paraba sp. 8	PNSJ	CC	+
Paraba tingauna (Kishimoto & Carbayo, 2012)	SSC	CC	
Paraba sp. 9	SSP	CC	+
Pasipha sp. 1	PNSJ	CC	+
Pasipha sp. 2	SFP	CC	+
Pasipha astraea (Marcus, 1951)	SMSP	CC	+
Pasipha atla Negrete & Brusa. 2016	MIS	CC	+
Pasipha backesi Leal-Zanchet et al., 2012	SFP	CC	+
Pasipha biseminalis (Riester, 1938)	Org	CC	+
Pasipha sp. 3	PNSJ	CC	+
Pasipha brevilineata Leal-Zanchet et al., 2012	SFP	CC	+
Pasipha sp. 4	PNSJ	CC	+
Pasipha caeruleonigra (Riester, 1938)	Org	CC	+
Pasipha cafusa (Froehlich, 1956)	Ubatuba	CC	+
Pasipha chimbeva (Froehlich, 1954)	SMSP	CC	+
Pasipha sp. 5	SFP	CC	+
Pasipha hauseri (Froehlich, 1959)	POA	CC	
Pasipha johnsoni Negrete & Brusa, 2016	MIS	CC	+
Pasipha sp. 6	SFP	CC	+
Pasipha mbya Negrete & Brusa, 2016	MIS	CC	
Pasipha mesoxantha Amaral & Leal-Zanchet, 2016	Smaria	CC	+
Pasipha sp. 7	PR	CC	+
Pasipha oliverioi (Froehlich, 1959)	Org	CC	+
Pasipha pasipha (Marcus, 1951)	SMSP	CC	+
Pasipha sp. 8	SSC, SSP	WS	
Pasipha sp. 9	NSC, PNSJ	MRE	
Pasipha pinima (Froehlich, 1954)	ORG, SMSP, SCS, SSP, x	WS	
Pasipha sp. 10	SSC	MRE-CC	
Pasipha plana (Schirch, 1929)	Org	CC	+
Pasipha sp. 11	SFP, SSP	WS	
Pasipha quirogai Negrete & Brusa, 2017	MIS	MRE	+
Pasipha rosea (Froehlich, 1954)	SMSP, PR	WS	
Pasipha sp. 12	Bocaina	CC	+
Pasipha splendida (Graff, 1899)	Org	CC	+
Pasipha sp. 13	PNSJ	CC	+
Pasipha tapetilla (Marcus, 1951)	NSC, SSC	WS	
Pasipha turvensis Amaral & Leal-Zanchet, 2016	Derrubadas	CC	+
Pasipha velina (Froehlich, 1959)	NSC	CC	
Pasipha velutina (Riester, 1938)	x		+

Geoplaninae 9	PNSJ	CC	+
Geoplaninae 10	PNSJ	CC	+
Geoplaninae 11	SSC	CC	+
Geoplaninae 12	PNSJ	CC	+
Geoplaninae 13	PNSJ	CC	+
Rhynchodeminae 1	NSC	CC	+
Rhynchodeminae 2	SFP	CC	+
Rhynchodemus hectori Graff, 1897	Org	CC	+
Rhynchodemus scius Du Bois-Reymond Marcus, 1955	Ubatuba	CC	+
Supramontana argentina Negrete et al., 2014	MIS	CC	
Geoplaninae 20	SSC	CC	+
Supramontana irritata Carbayo & Leal-Zanchet, 2003	SFP	CC	+
Geoplaninae 14	NSC	CC	+
Geoplaninae 15	SSC	CC	+
Xerapoa hystrix Froehlich, 1954	PR, SMSP	WS	
Xerapoa sp. 1	SSP, SSC	WS	
Xerapoa sp. 2	SSP	CC	+
Xerapoa pseudorhynchodemus (Riester, 1938)	ORG, SMSP, SCN, SCS, PR, x	WS	
Xerapoa sp. 3	PNSJ	CC	+
Xerapoa sp. 4	SFP	CC	+
Xerapoa trina (Marcus, 1951)	SMSP, Org	WS	
Xerapoa una Froehlich, 1954	NSC	CC	+
Xerapoa sp. 5	PNSJ	CC	+

Chapter 5

Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest: expanding the study area and exploring niche modeling

This manuscript has not yet been submitted for publication. **Lago-Barcia D**, DaSilva MB, Conti LA, Carbayo F. Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest: expanding the study area and exploring niche modeling. Ready for submission.

Abstract

Here we study an area, approximately 1600 km in length, of the Atlantic forest, from the State of Espirito Santo to the State of Rio Grande do Sul, in search of Areas of Endemism (AoE) of land planarians (Geoplaninae) and their causal factors. We used 1888 records of 371 species and Endemicity Analysis and Geographic Interpolation of Endemism numerical methods, to uncover AoE. We also carried out a Niche Modeling of three genera inside the subfamily to see the suitability regions where these genera were distributed during the Mid Pliocene, the Late Interglacial Maximum, the Late Glacial Maximum and the present time. Seven AoE were identified with the Endemicity Analysis, and 18 with the Geographic Interpolation of Endemism. These endemic patterns of land planarians can be explained through processes of reduction and expansion of suitability areas formed from the Neogene to the present date. These processes of reduction and expansion of suitability areas are linked to the forest reductions occurred during these time periods. Planarians have shown to be an optimal model for fine-scale studies of AoE and in the future, robust phylogenies will help corroborate such paleoecological models.

Introduction

Land flatworms (Platyhelminthes, Tricladida, Geoplanidae) are free-living organisms distributed throughout the world except for the high latitudes (Sluys et al. 2009; Carbayo et al., 2013). More than 940 species are described (Sluys, 2016). The highest diversity of land planarians is in tropical areas (Sluys, 1999). The subfamily Geoplaninae is limited to the Neotropical region (Bulnes et al., 2018; Iturralde et al., 2021), excepting a few species, such as *Obama nungara* Carbayo et al., 2016 found extensively in Europe and considered to be introduced (Álvarez-Presas et al., 2014a; Carbayo et al., 2016; Lago-Barcia et al., 2019; Lago-Barcia et al., 2020a; Negrete et al., 2020; Justine et al., 2020a), and *Amaga expatria* Jones & Sterrer, 2005 originally described from the Bermuda Islands (Jones and Sterrer, 2005) and also found in Martinique (Justine et al., 2020b). Over 340 described species are known from the Neotropical region (http://planarias.each.usp.br/, accessed in November 2021) plus 98 undescribed species recently reported from the Brazilian Atlantic forest (Lago-Barcia et al., 2020b).

The Brazilian Atlantic forest (AF) is, nowadays, one of the most threatened biomes in the world (Mori et al., 1981; Rands et al., 2010; Tabarelli et al., 2010). From its original extension, only 11 – 16% is left (Ribeiro et al., 2009). It is highly fragmented into small isolated portions, part of them covered with secondary growth forests (Metzger, 2000). In view of the progresive deforestation, E. M. Froehlich (1954) expressed the need of accelerating sampling effort to be able to address the study to differentiate polytypic from ‘good’ species.

Land planarians are organisms with a low vagility and restricted distributions (Sluys, 1995; Winsor et al., 1998). Due to their low capacity to withstand dehydration, they must live in humid habitats and stay refuged during the day (Sluys 1999; Winsor et al., 2004). These animals present a high sensitivity to alterations in their environment (Carbayo et al., 2002). These biological aspects make these organisms good models for biogeographic studies and conservation biology (Ron, 2000; Álvarez-Presas et al.,

2011) since the distribution of organisms with such properties can help identify natural areas for conservation (Vane-Wright et al., 1991; Martínez-Hernández et al., 2015).

An Area of Endemism (AoE) is a hypothesized area often defined by two or more endemic species living inside them, presenting substantial congruence among their range limits (Morrone, 1994; Platnick, 1991). In a recent paper, Lago-Barcia et al. (2020) explored distributions of land planarians in the southern region of the Brazilian Atlantic forest. These authors combined an Endemicity Analisis (EA) (Szumik et al., 2002; Szumik & Goloboff, 2004) and a Geographic Interpolation of Endemism (GIE) (Oliveira et al., 2015), through the use of a protocol designed by Da Silva et al. (2015) in order to detect areas of endemisms (AoE). Results showed that land planarian species inside the Atlantic forest have a very restricted distribution and are partially overlapped one over another, generating numerous AoE (Lago-Barcia et al., 2020b).

The AoE discovered by Lago-Barcia et al. (2020b) are, from north to south: AoE of the Serra dos Órgãos (ORG), AoE of Serra do Mar de São Paulo (SMSP), AoE of Southern São Paulo (SSP), AoE of Paraná (PR), AoE of Northern Santa Catarina (NSC), AoE of Southern Santa Catarina (SSC), AoE of São Francisco de Paula (SFP), AoE of Porto Alegre (POA), and AoE of Misiones (MIS). Seven smaller AoE bearing endemic species with a single record were discovered as well (see Fig. 7 in Lago-Barcia et al., 2020b).

The present study is a continuation of Lago-Barcia's et al. (2020b) paper. Here we increased considerably the number of records and species, and expanded the study area to the northern regions of the AF, up to the state of Espírito Santo, thus embracing an area with approximately 1600 km in length. The addition of these new records provided a more robust identification of the AoE previously discovered and disclosed new AoE.

Materials and Methods

The study area comprises a region covered with Brazilian Atlantic forest, between the states of Espírito Santo and Rio Grande do Sul, and reaching the Argentinean region of Misiones to the West, encompassing a 1600 km long range from Northeast to Southwest (Fig. 1).

We explored records of land planarians from two sources, namely from the literature and from our field data. A record is defined here as an observation of a specimen of a certain species in a given location. 571 records were recovered from the literature (including here those compiled for Lago-Barcia's et al. (2020b) work (see Supp. Tab. 1). We used Google Maps to recover geographic coordinates of locations mentioned in the literature but lacking coordinates.

Our field data was predominantly compiled from six intensively sampled conservation areas across the Atlantic forest (Fig. 1). Aproximately ~200 person-hour of sampling effort was invested in each of the six areas. These areas are, from North-West to South-East, Reserva Biológica Augusto Ruschi (Santa Teresa, State of Espírito Santo), Parque Estadual do Desengano (Santa Maria Madalena, state of Rio de Janeiro), Parque Nacional da Serra dos Órgãos (Teresópolis, state of Rio de Janeiro), Parque Nacional da Serra da Bocaina (São José do Barreiro, state of São Paulo), Estação Biológica de Boraceia (Salesópolis, state of São Paulo), and Parque Estadual da Serra da Cantareira (São Paulo, state of São Paulo) (Fig. 1).

Additionally, data from sporadic samplings in other localities between 2009 and 2020 were also considered in the study.

The specimens were collected manually during daylight hours from under rocks, fallen leaves, and logs, and during night time hours, when the animals are more active, by searching the soil with the help of lanterns. We used the GPS device Garmin E-Trex to record the geographic coordinates of each specimen with a maximum error of ~50 m for most of the specimens collected. We also used Google Maps to recover geographic coordinates of a few not georeferenced specimens collected.

Specimens were initially identified as morphospecies according to their external appearance. Specimens with a very distinct color pattern of the body were classified as Geoplaninae if examination of the internal organs was not possible (e.g., Geoplaninae 1). Among the remaining specimens, histological sections of the cephalic region, pharynx and copulatory apparatus of one or more representatives of most morphospecies were prepared whenever possible and examined with a light microscope following the procedures described in Carbayo and Almeida (2015). The internal morphology was compared against that of other morphospecies and also known species to check for conspecificity. These morphospecies were finally classified into one of the following five categories: known species (e.g., *Geoplana chita* Schultze & Müller, 1857), undescribed species of a known genus (e.g., *Geoplana* sp. 1), undescribed species of an undescribed genus (e.g., gen. 1 sp. 1), undescribed species of an undetermined genus (e.g., Geoplaninae 1), and uncertain species of a known genus (e.g., *Imbira* cf. *marcusi*, *Luteostriata* sp.). In the latter situation, the geographic distribution of the species was only explored for the distribution of the genus (see below). For some species which might represent a species complex (e.g., *Obama carinata*, pers. obs.), only the record of the holotype was considered. Some specimens of *Cephaloflexa bergi*, and *Imbira marcusi* in Lago-Barcia et al. (2020b) were corrected for the present study, since we now know they consist of species complex.

A total of 1317 records came from our field data. The sum of these records plus the 571 records from the literature gives a total of 1888 records from 371 species.

The Endemicity Analysis (EA) (Szumik et al., 2002; Szumik & Goloboff, 2004) was carried out using the software program NDM/VNDM. Different grid origins were tested to find eventual hidden AoE caused by the grid's position, and the coordinates used for the analysis were -59.0, -10.9. The analyses were also run with four cell sizes, namely 0.1º, 0.2º, 0.3º, and 0.5º. We computed consensus areas of endemism through a strict consensus or tight consensus rule (Aagesen et al., 2013, Szumik et al., 2006) using

5% similarity in species distribution between different sets of cells (see details in Lago-Barcia et al., 2020b).

The Geographic Interpolation of Endemism (GIE) (Oliveira et al., 2015) was carried out using the Biodinamica package (Oliveira et al., 2019) integrated in the Dinamica-EGO modeling platform (http://csr.ufmg.br/dinamica/, accessed in November 2021). Biodinamica is a tool developed using Dinamica-EGO freeware (Soares-Filho et al. 2013), with the intention of implementing spatial biogeographic analyses (among other types of analyses), into a single integrated software environment (Oliveira et al., 2019). Inside the package, the GIE tool functions without the use of any GIS software and with a simple user-friendly interface capable of generating result outputs with consensus raster maps, figures showing the resulted AoEs, tables with the species that occur in each AoE, and a report with statistical information (Oliveira et al., 2019). This software permits an inexperienced user of Geographic Information System mapping (GIS) or modeling softwares to be able to carry out a complete and detailed GIE analysis, with its centroid calculation, interpolation and AoE identification (Oliveira et al., 2019). Whereas before 2019 only an experienced GIS software user was able to run a GIE analysis using GIS software. The GIE analyses were run under the following parameters: four to eight classes were used; size of the area of influence set to values between 20 and 1200; and default predetermined weights.

Finally, the resulting endemic patterns were delimited by means of the combined criteria developed by DaSilva et al. (2015), whose protocol was applied for a final delimitation of the recovered AoE. (To see a more detailed explanation of the protocol, refer to DaSilva et al., 2015 and Lago-Barcia et al., 2020b).

Three Niche Models (NM) for the present and paleoclimatic conditions were generated based on occurrence records for the genera *Supramontana*, *Choeradoplana* and *Cratera,* respectively. These genera were chosen because they are widespread throughout the study area, and are the genera with the highest number of species in the study.

The NM was based on the correlation of occurrence of the analyzed genera as a function of climatic-environmental variables through Bioclimatic Envelopes (Bioclim) and Maximum Entropy (Maxent) algorithms using the BioDinamica toolset (Oliveira et al. 2019) implemented in Dinamica-EGO software (Soares-Filho et al. 2013). Such models produce estimates of the occurrence of taxonomic groups by calculating the probability distribution of their maximum entropy (Phillips et al., 2006). Details on the specifications and applications of these models can be found in works such as Waren & Seifert (2011); Radosavljevic & Anderson (2014); Venne & Currie (2021) among others. To calibrate and evaluate the quality of the models, the species data was divided into a training set (70% of the records) and a test or validation set (30% of the occurrences). The models were evaluated using the AUC (area under the curve) that measures the discriminatory ability of the model, with values above 0.8 being considered here of high accuracy (Manel et al., 2001; Lima et al., 2020). The normalized values generated by the model were categorized into 0.5 - 0.7 = medium and 0.7 - 1 = high to better represent their spatial distribution.

In the case of bioclimatic parameters, the climatic variables obtained from the WorldClim database (http://www.worldclim.org/, accessed on November 2021) were used, derived from information obtained from fixed monitoring points for temperature and rainfall, with predictive distribution models representing 19 variables, described in Table 1. Principal Component analysis and Multivariate Environmental Similarity Surface (MESS) were performed to establish the correlation of variables for the study region and parameters with more than 80% correlation were eliminated. In the case of paleoclimate data, models generated for three scenarios were used: Last Glacial Maximum (LGM) 23 K years, Last Interglacial Maximum (LIM) 130 K years (downloaded from WorldClim v 1.4 www.worldclim.org/; accessed on November 2021); and Mid Pliocene (MP) 1.3 M years (downloaded from EcoClimate www.ecoclimate.org/; accessed on November 2021) in 30 arc-seconds (Karger et al. 2017).

Tab. 1. Climatic variables used in the study, downloaded from Worldclim data base (http://www.worldclim.org/). Climatic variables excluded from the Niche Models presented parameters with more than 80% correlation.

Code of climatic variable	Climatic variable	Used for Niche Modeling
BIO1	Annual Mean Temperature	X
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	
BIO3	Isothermality (BIO2/BIO7) (* 100)	
BIO4	Temperature Seasonality (standard deviation *100)	X
BIO5	Max Temperature of Warmest Month	
BIO6	Min Temperature of Coldest Month	X
BIO7	Temperature Annual Range (BIO5-BIO6)	X
BIO8	Mean Temperature of Wettest Quarter	
BIO9	Mean Temperature of Driest Quarter	
BIO10	Mean Temperature of Warmest Quarter	
BIO11	Mean Temperature of Coldest Quarter	
BIO12	Annual Precipitation	X
BIO13	Precipitation of Wettest Month	
BIO14	Precipitation of Driest Month	
BIO15	Precipitation Seasonality (Coefficient of Variation)	
BIO16	Precipitation of Wettest Quarter	
BIO17	Precipitation of Driest Quarter	
BIO18	Precipitation of Warmest Quarter	X
BIO19	Precipitation of Coldest Quarter	

Abbreviations

AoE: Area of endemism

AF: Atlantic forest

AR: Area of endemism of Augusto Ruschi

DER: Area of endemism of Derrubadas

EA: Endemicity Analysis

GC: Area of endemism of General Carneiro

GIE: Geographic Interpolation of Endemism

LGM: Last Glacial Maximum

LIM: Last Interglacial Maximum

MP: Mid Pliocene

MG: Area of endemism of Minas Gerais

MIS: Area of endemism of Misiones

NDM/VNDM: Software that carries out an Endemicity Analysis

NM: Niche Models

NSC: Area of endemism of North Santa Catarina

ORG: Area of endemism of the Serra dos Órgãos

POA: Area of endemism of Porto Alegre

PR: Area of endemism of Paraná

SC: Area of endemism of Santa Catarina

SFP: Area of endemism of São Francisco de Paula

SJ: Area of endemism of P. N. de São Joaquim

SJB: Area of endemism of São José do Barreiro

SMM: Area of endemism of Santa Maria Madalena

SMSP: Area of endemism of Serra do Mar de São Paulo

SSC: Area of endemism of South Santa Catarina

SSP: Area of endemism of Southern São Paulo

TB: Area of endemism of Três Barras

UBA: Area of endemism of Ubatuba

Results

Endemicity Analysis

The grid origin that best fitted our dataset was -59.0 (X), -10.9 (Y). The AoE generated using the cell size 0.1º are the same as those generated with larger cell sized grids (see below), but with 0.1º, the AoEs are discontinuous and identified by a smaller number of endemic species (results not shown). The analysis using a cell size of 0.2º generated six consensual AoEs. They are, from north to south, the AoE Augusto Ruschi (AR) (Fig. S1), the AoE Serra dos Órgãos (ORG) (Fig. S2), the AoE Serra do Mar de São Paulo (SMSP) (Fig. S3), the AoE North Santa Catarina (NSC) (Fig. S4), the AoE South Santa Catarina (SSC) (Fig. S5), and the AoE São Francisco de Paula (SFP) (Fig. S6).

The analysis with 0.3º cell size retrieved the same AoEs as in the 0.2º analysis (differing in size and defined by a different composition of species in some cases), plus the AoE of Misiones (MIS; Fig. S7). The analysis employing 0.5º cell size grids generated AoE which overlap with those generated with cell size of 0.2º and 0.3º (results not shown).

In total, seven AoEs were identified with EA (Tab. 2), namely AR (supported by a total of 11 endemic species), ORG (15), SMSP (10), NSC (7), SSC (3), SFP (6) and MIS (2).

Geographic Interpolation of Endemism

All GIE (Geographic Interpolation of Endemism) analyses, executed varying the number of classes, and the size of the area of influence for each class, retrieved the same 18 AoE: AR, ORG, SMSP, AoE Southern São Paulo (SSP), AoE Parana (PR), NSC, SSC, SFP, AoE Porto Alegre (POA), MIS, AoE Minas Gerais (MG), AoE São José do Barreiro (SJB), AoE Ubatuba (UBA), AoE Santa Maria Madalena (SMM), AoE São Joaquim (SJ), AoE Derrubadas (DER), AoE General Carneiro (GC), and the AoE Três

Barras (TB). Fig. 2 shows the results retrieved with six classes (with areas of influence adjusted to 50, 100, 200, 400, 800, and predetermined weights given by the software).

AoE	EA	GIE
Augusto Ruschi (AR)	✓	✓
Derrubadas (DER)		✓
General Carneiro (GC)		✓
Minas Gerais (MG)		✓
Misiones (MIS)	✓	✓
North Santa Catarina (NSC)	✓	✓
Paraná (PR)		✓
Porto Alegre (POA)		✓
Santa Maria Madalena (SMM)		✓
São Francisco de Paula (SFP)	✓	✓
São Joaquim (SJ)		✓
São José do Barreiro (SJB)		✓
Serra dos Órgãos (ORG)	✓	✓
Serra do Mar de São Paulo (SMSP)	✓	✓
South Santa Catarina (SSC)	✓	✓
Southern São Paulo (SSP)		✓
Três Barras (TB)		✓
Ubatuba (UB)		✓

Tab. 2. Areas of Endemism and methodology through which they were identified. The AoE are listed alphabetically.

Niche modeling

The NM (Niche Model) generated for the genus *Choeradoplana*, for the present conditions, indicates suitable habitats for a large area following the coastal region of Brazil between parallels 20 and 33 (Fig. 3A). There are two discontinuous zones, the first one in the north coinciding with the AoE of AR, and a more extensive one projecting westward, and encompassing the continental portion of Brazil until southern Paraguay. This latter zone encloses the endemic regions TB, GC, and MIS. A similar suitable large area occurs in relation to *Supramontana* (Fig. 4A). In the case of *Cratera* (Fig. 5A), the suitable area is similar to that of the other two genera, although it presents a higher discontinuity and suitable 'islands' to the north, next to the endemic areas AR, SMM and ORG, and to the south, isolated, SSC, NSC, SJ, SFP and POA, besides two additional zones to the west, namely CG combined with TB, and MIS.

In the case of the paleoclimatic model of the LGM (Last Glacial Maximum) of 23 K years there is a considerable change of suitable conditions inland, especially in the case of the genera *Choeradoplana* (Fig. 3B) and *Supramontana* (Fig. 4B). In general, there is a noticeable decrease in optimum conditions, but apparently no isolated zones were formed. In the case of *Cratera* (Fig. 5B) the overall conditions have little variation in comparison to current patterns.

In the paleoclimatic model of the LIM (Last Interglacial Maximum, 130 K years), there is a significant expansion of suitability areas for the three genera analyzed. In the case of *Supramontana* (Fig. 4C) all AoE are connected by suitable areas. In the cases of *Choeradoplana* (Fig. 3C) and *Cratera* (Fig. 5C), although there is an expansion of high and medium suitability areas, the northern suitable regions extending over SMM and AR apparently remained isolated.

The model generated for the MP (Mid Pliocene, 3.5 M years), shows that the general climatic conditions are more similar to the LIM, although a similar expansion of suitability areas was not observed. In fact, areas of high suitability remained closer to the present-day patterns. The genus *Choeradoplana* (Fig. 3D) and *Supramontana* (Fig.

4D) showed continuous areas throughout the coastal region, whereas the genus *Cratera* (Fig. 5D) presents an isolated suitable area in southern Brazil corresponding to the POA and SFP endemism areas. *Choeradoplana* and *Cratera* also show suitability areas around the western localities that correspond with Derrubadas and the argentinean region of Misiones.

Discussion

The methodological approach applied herein to discover AoE was the same as in Lago-Barcia et al. (2020b). Our results retrieved the same AoE in the overlapping study area, i.e, the region between the states of Rio de Janeiro and Rio Grande do Sul, except for GC and the AoE of Matinhos-PR in Lago-Barcia et al. (2020b). GC was not recovered in Lago-Barcia et al. (2020b) because there were no records available at that time. In contrast, with the current records, now it was revealed with GIE and presents four endemic species. The EA did not identify GC because the records for this area were located in one same geographic coordinate, and the software NDM uses the presence of a species in two different cells to identify an AoE. Matinhos-PR appeared as a separate AoE in Lago-Barcia et al. (2020b), though in the present study it is merged with PR which is congruent with the proximity between the two AoE. The correction of some records of the species found in the localities of Matinhos, Morretes and Curitiba have generated the fusion between these two AoE, as the area of influence in the 3 localities has increased from Lago-Barcia et al. (2020b) to the present study.

The new records added in the present study (approximately 72% of the total (522 records included in Lago-Barcia et al., 2020b)) were mostly for new localities, mainly located to the North of the Parque Estadual da Cantareira and not considered in Lago-Barcia et al., 2020b. Therefore they did not influence the identification of previously identified AoE, except POA in the EA. The GIE analysis recovered POA, but the EA did not. The EA failed because the three species giving endemicity score in Lago-Barcia

et al. (2020b), are no longer found inside two or more different cells, due to the positioning of the grid. This evidences the influence of the positioning of the grid origin, and the importance of using an integrative approach by using several methodologies as GIE was successful in recovering POA. Additionally to these AoE previously detected by Lago-Barcia et al. (2020b), two new AoE were discovered to the North of the study area, namely Reserva Biológica Augusto Ruschi (AR) and AoE Minas Gerais (MG). For these new AoE there were no records in Lago-Barcia et al. (2020b) and therefore represent new AoE of land flatworms in the Brazilian AF. The new AoE AR was detected by both numerical methodologies (EA and GIE).

The new AoE MG was identified only by the GIE analysis. As in the case of the AoE POA explained above, this AoE was not found by the EA due to the fact that the records for all species present in the area were located within the same grid cell, and the software NDM uses the presence of a species in two different cells to identify an AoE.

Out of the total number of AoE detected in the present study (18), only seven AoE were detected by both methodologies (see Table. 2). The reason for this was mainly that the records for the AoE not detected by EA, are all either a single specimen of the species recorded, or the different records of the species all belong to a single geographic location (or point). EA cannot identify AoE based on a single location or a single record, as already mentioned before.

Clusters of AoE retrieved in this study also match AoE identified for other major groups of plants and animals (Kinzey, 1982; Cracraft, 1985; Morrone, 2001; Amorim and Pires, 1996; Costa et al., 2000; Silva et al., 2004; Pinto-da-Rocha et al., 2005; DaSilva & Pinto-da-Rocha, 2011; Prado et al., 2015, Garrafoni et al., 2017, Gomes-da-Silva and Forzza, 2021; Dalapicolla et al., 2021) suggesting the Atlantic forest as an important centre of endemism.

The restricted range of distribution of most land flatworm species pointed out by several authors (Sluys, 1995; Winsor et al., 1998) is corroborated in this study. It is precisely this property that makes land planarians valuable for the detection areas of

endemism. Broadly, some animal groups share similar restricted distributions with land planarians of the AF that identify similar AoE, such as frogs (Brown et al., 2020), crickets (Melo, 1994), orchid bees (Garrafoni et al., 2017), dung beetles (Silva & Vaz-de-Mello, 2020), harvestmen (DaSilva et al., 2015), or ferns and lycophytes (de Souza et al., 2021).

The relictual nature of the distributions of some taxa of planarians has been ascribed to climatic variations in the Neotropic during the Neogene (Lago-Barcia et al., 2020b). Fluctuations between wet and dry climates reduced the range of forests in certain regions, or refuges (Haffer, 1897; Ledru et al., 2005; Saia et al., 2008; Carnaval et al., 2009; D'Horta et al., 2011). Paleo-ecological models of habitat fragmentation in the AF have demonstrated a reduction in forestal environments and an increase in open landscapes (Carnaval & Moritz, 2008). These forest reductions maintained a more humid environment in the refuges, offering a more ecologically stable habitat for long-term taxa survival and speciation would occur in different refuges due to isolation of populations. These models support an explanation for the high endemicity found for land planarians in these AoE lacking clear geographic barriers (Lago-Barcia et al., 2020b).

Many factors are potentially able to shape the distribution of the species of the AF and to influence the relationships between them (Costa, 2003). Among these factors, there can be considered intrinsic attributes of every species, such as responses to the same environmental or geologic characteristics or different response times of species isolated by the same barrier (Zink et al., 2001). Lago-Barcia et al. (2020b) pointed some causes for the formation of AoEs of flatworms in the AF, such as the origin and maintenance of large river valleys, as Rio Ribeira do Iguape and Rio Paraíba do Sul (Fig. 1), the uplifting of mountains and the reduction of forestal spots during climatic fluctuations. Those causes are ontologically related to each other, as the humid forest are more stable in slopes of mountains and the barriers between AoE are the large

valleys and tops of mountains, for example (DaSilva et al., 2015, Lago-Barcia et al., 2020b).

In the present work, we were able to compare the current geographic pattern of endemism of the flatworms -represented by their AoE- with models of past paleoclimates. On the basis of the paleoclimatic models, we hypothesize that the vicariant factors of forest reduction could have influenced the formation of the AoE identified in the present study, since there is a spatial coincidence between them. Hotter periods show an expansion of suitability areas, coinciding for the three genera analysed, namely *Choeradoplana, Cratera* and *Supramontana*. Unfortunately a robust phylogenetic framework of the group is lacking, so our analyses cannot be properly discussed from a historical perspective. A phylogeny would be appropriate to test whether forest reductions were directly responsible for the speciation events and consequent formation of AoE. We chose speciose genera restricted to the delimited study area, to try to identify the allopatric processes of speciation that happened between AoE. Along the four different paleoclimatic periods modelled, expansions and reductions of the suitability areas for the three genera occurred. From the LIM to the present date, the three genera show that the suitability areas were reduced and fragmented into suitability 'islands' such as the areas of Augusto Ruschi to the north of the study area, and the area of Misiones, or the area of Três Barras and General Carneiro for *Cratera*. The formation of these suitability 'islands' could represent areas of isolation and speciation inside the Southern Atlantic Forest. Therefore, the hypotheses to be tested would be whether these isolation and speciation processes match the time estimation of species divergence. Forest refuges were assumed to have existed mainly during the Pleistocene (~2-0.02 mya; Carnaval & Moritz, 2008), but older global coolings are known since Late Miocene (~14 mya, Ravelo et al., 2004, Holbourn et al., 2013) and could have influenced the Atlantic Forest and its biota. The phylogeographic structure of the species *Cephaloflexa bergi* was assessed by Álvarez-Presas et al.

(2014b) and the main divergences for that species were dated up to 8 mya, though the distribution of *C. bergi* is too widespread to be useful for temporal studies.

Conclusions

In the present study, we effectively identified several planarian AoE along the AF using numerical methods. Some AoE only present species with a single record (only have been found once) or only present non-described morphospecies (such as AR with the exception of *Choeradoplana onae*, *Ch. albonigra*, *Ch. claudioi*, *Issoca rezendei* and *Issoca assanga*). These cases might be evidence of a lack in sampling efforts, as species only found once in a given locality, will probably be found and recorded again if higher sampling efforts are invested. On the other hand, an area where all species found are non-described species will indicate that the true diversity of this locality is still underrepresented in the literature, and an effort should be invested to describe the planarian diversity of the locality.

Planarians are an optimal model for fine-scale studies of AoE. Depending on the chosen taxa, its record data available and the area being studied, animals with small range distributions and with environmental limitations may help to detect AoE at a small scale.

The endemic distribution of land planarians in the Atlantic Forest seems to be affected by processes of reduction and expansion of suitability areas formed from the Neogene to the present date. These processes of reduction and expansion of suitability areas are linked to the forest reductions occurred during these time periods. In the future, robust phylogenies will help corroborate such hypotheses.

References

Aagesen L, Szumik C, Goloboff P. 2013. Consensus in the search for areas of endemism. *Journal of Biogeography* 40: 2011–2016.

Álvarez-Presas M, Mateos E, Tudó A, Jones H, Riutort M. 2014a. Diversity of introduced terrestrial flatworms in the Iberian Peninsula: a cautionary tale. *PeerJ* 2: e430. DOI 10.7717/peerj.430.

Álvarez-Presas M, Sánchez-Gracía A, Carbayo F, Rozas J, Riutort M. 2014b. Insights into the origin and distribution of biodiversity in the Brazilian Atlantic forest hotspot: a statistical phylogeographic study using a low-dispersal organism. *Heredity* 112: 656–665. https://doi.org/10.1038/hdy.2014.3 PMID: 24549112

Álvarez-Presas M, Carbayo F, Rozas J, Riutort M. 2011. Land planarians (Platyhelminthes) as a model organism for fine-scale phylogeographic studies: Understanding patterns of biodiversity in the Brazilian Atlantic Forest hotspot. *Journal of Evolutionary Biology* 24(4): 887-896.

Amorim DS, Pires MRS. 1996. Neotropical biogeography and a method for a maximum biodiversity estimation. In: Bicudo CEM, Menezes NA, editors. Biodiversity in Brazil. A First Approach. Conselho Nacional de Desenvolvimento Cientifico e Tecnologico, São Paulo; p. 183–219.

Brown JL, Paz A, Reginato M, Renata CA, Assis C, Lyra M, …, Carnaval AC. 2020. Seeing the forest through many trees: Multi-taxon patterns of phylogenetic diversity in the Atlantic Forest hotspot. *Diversity and Distributions* 26(9), 1160-1176.

Bulnes VN, Grau JH, Carbayo F. 2018. A new Chilean genus and species of land planarian (Platyhelminthes: Tricladida, Geoplaninae) with cephalic retractor muscle and adenodactyl. *Journal of Natural History* 52: 39-40, 2553-2566. DOI: 10.1080/00222933.2018.1538468

Carbayo F, Álvarez-Presas M, Olivares CT, Marques FPL, Froehlich EM, Riutort, M. 2013. Molecular phylogeny of Geoplaninae (Platyhelminthes) challenges current classification: proposal of taxonomic actions. *Zoologica Scripta* 42: 508–528. doi:10.1111/ zsc.12019

Carbayo F, Almeida AL. 2015. Anatomical deviation of male organs of land planarians from Rio de Janeiro, Brazil, with description of two new species of Cratera (Platyhelminthes, Tricladida). *Zootaxa* 3931(1): 027-040.

Carbayo, F, Álvarez-Presas M, Jones HD, Riutort M. 2016. The true identity of *Obama* (Platyhelminthes: Geoplanidae) flatworm spreading across Europe. *Zoological Journal of the Linnean Society* 177(1): 5–28. https://doi.org/10.1111/zoj.12358

Carbayo F, Leal-Zanchet AM, Vieira EM. 2002. Terrestrial flatworm (Platyhelminthes: Tricladida: Terricola) diversity versus man-induced disturbance in an ombrophilous forest in southern Brazil. *Biodiversity & Conservation* 11(6): 1091-1104.

Carnaval AC, Hickerson MJ, Haddad CFB, Rodrigues MT, Moritz C. 2009. Stability predicts genetic diversity in the Brazilian Atlantic Forest Hotspot. *Science* 323: 785–789. https://doi.org/10.1126/science.1166955 PMID: 19197066

Carnaval AC, Moritz C. 2008. Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. *Journal of Biogeography* 35(7): 1187-1201.

Costa LP, Fonseca GAB, Fonseca MT. 2000. Biogeography of South America forest mammals: endemism and diversity in the Atlantic Forest. *Biotropica* 32: 872–881.

Costa LP. 2003. The historical bridge between the Amazon and the Atlantic Forest of Brazil: a study of molecular phylogeography with small mammals. *Journal of biogeography* 30(1): 71-86.

Cracraft J. 1985. Historical biogeography and patterns of differentiation within the South American avifauna: areas of endemism. *Ornithological Monography* 36: 49–84.

D'Horta FM, Cabanne GS, Meyer D, Miyaki CY. 2011. The genetic effects of Late Quaternary climatic changes over a tropical latitudinal gradient: diversification of an Atlantic Forest passerine. *Molecular Ecology*. 20: 1923–1935. https://doi.org/10.1111/j.1365-294X.2011.05063.x PMID: 21410807

Dalapicolla J, Abreu EF, do Prado JR, de Almeida Chiquito E, de Oliveira Roth PR, de Góes Brennand PG, …, Bovendorp RS. 2021. Areas of endemism of small

mammals are underprotected in the Atlantic Forest. *Journal of Mammalogy* 102(5): 1390-1404.

DaSilva MB, Pinto-da-Rocha R, DeSouza AM. 2015. A protocol for the delimitation of areas of endemism and the historical regionalization of the Brazilian Atlantic Rain Forest using harvestmen distribution data. *Cladistics* 31: 692–705.

DaSilva MB, Pinto-da-Rocha R. 2011. A historia da Mata Atlantica atraves da distribuicão dos opiliões (Arachnida). In: Carvalho CJB, Almeida EAB, editors. Biogeografia da America do Sul: Padrões e Processos. Editora Roca, São Paulo; p. 221–238.

de Souza JF, Bueno ML, Salino A. 2021. Atlantic Forest: centres of diversity and endemism for ferns and lycophytes and conservation status. *Biodiversity and Conservation* 30(7): 2207-2222.

Froehlich CG. 1954. Sobre morfologia e taxonomia das Geoplanidae. *Boletim da Facultade de Filosofia e Ciencia da Universidade de São Paulo. (Zool.)* 19: 195-251.

Garrafoni ARS, Moura FR, Lourenco AP. 2017. Areas of endemism in the Atlantic Forest: quantitative biogeography insights from orchid bees (Apidae: Euglossini). *Apidologie* 48: 513. https://doi.org/10. 1007/s13592-017-0494-6.

Gomes-da-Silva J, Forzza RC. 2021. Two centuries of distribution data: detection of areas of endemism for the Brazilian angiosperms. *Cladistics* 37(4): 442-458.

Haffer J. 1987. Biogeography of Neotropical birds. In: Whitmore TC, Prance GT, editors. Biogeography and Quaternary history in tropical America. Oxford: Clarendon Press. p. 105–150.

Holbourn A, Kuhnt W, Clemens S, Prell W, Andersen N. 2013. Middle to late Miocene stepwise climate cooling: Evidence from a high-resolution deep water isotope curve spanning 8 million years. *Paleoceanography* 28(4): 688-699.

Iturralde GG, Allgayer H, Valiati VH, Leal-Zanchet AM. 2021. Seeing the true colours: three new species of *Obama* (Platyhelminthes: Continenticola) from remnants of Atlantic forest in southern Brazil based on an integrative approach. *Invertebrate Systematics* 35(3): 312-331.

Jones HD, Sterrer W. 2005. Terrestrial planarians (Platyhelminthes, with three new species) and nemertines of Bermuda. *Zootaxa* 1001: 31–58

Justine J-L, Winsor L, Gey D, Gros P, Thévenot J. 2020a. Obama chez moi! The invasion of metropolitan France by the land planarian Obama nungara (Platyhelminthes, Geoplanidae). *PeerJ* 8: e8385. https://doi.org/10.7717/peerj.8385

Justine JL, Gey D, Thévenot J, Gastineau R, Jones HD. 2020b. The land flatworm Amaga expatria (Geoplanidae) in Guadeloupe and Martinique: new reports and molecular characterization including complete mitogenome. *PeerJ* 8: e10098.

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, …, Kessler M. 2017. Climatologies at high resolution for the earth's land surface areas. *Scientific data* 4(1): 1-20.

Kinzey WG. 1982. Distribution of primates and forest refuges. In: Prance GT, Editor. Biological diversification in the tropics. Columbia University Press, New York, New York; 1982. p. 455–482.

Lago-Barcia D, González-López JR, Fernández-Álvarez FÁ. 2020a. The invasive land flatworm Obama nungara (Platyhelminthes: Geoplanidae) reaches a natural environment in the oceanic island of São Miguel (Açores). *Zootaxa* 4830(1): 197–200.

Lago-Barcia D, DaSilva MB, Conti LA, Carbayo F. 2020b. Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest. *PLoS ONE* 15(7): e0235949. https://doi.org/10.1371/journal.pone.0235949

Lago-Barcia D, Fernández-Álvarez FÁ, Brusa F, Rojo I, Damborenea C, Negrete L, Grande C, Noreña C. 2019 Reconstructing routes of invasion of Obama nungara (Platyhelminthes: Tricladida) in the Iberian Peninsula. *Biological Invasions* 21(2): 289–302.

Ledru MP, Rousseau DD, Cruz FW Jr, Riccomini C, Karmann I, Martin L. 2005. Paleoclimate changes during the last 100,000 yr from a record in the Brazilian Atlantic rainforest region and interhemispheric comparison. *Quartenary Res*. 64: 444–450.

Lima LF, Weissman M, Reed M, Papudeshi B, Alker AT, Morris MM, …, Dinsdale EA. 2020. Modeling of the coral microbiome: the influence of temperature and microbial network. *Mbio* 11(2) e02691-19.

Manel S, Williams HC, Ormerod SJ. 2001. Evaluating presence–absence models in ecology: the need to account for prevalence. *Journal of applied Ecology* 38(5): 921-931.

Martínez-Hernández F, Mendoza-Fernández AJ, Pérez-García FJ, Martínez-Nieto MI, Garrido-Becerra JA, Salmerón-Sánchez E, …, Mota JF. 2015. Areas of endemism as a conservation criterion for Iberian gypsophilous flora: a multi-scale test using the NDM/VNDM program. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology* 149(3): 483-493.

Mello, F.A.G. 1994. Sistemática, distribuição e diferenciação de grilos do gênero Aracamby Mello, 1992 nas matas costeiras do sudeste do Brasil e sistema insular adjacente: aspectos morfológicos, cromossômicos e comportamentais (Orthoptera: Grylloidea: Phalangopsidae). PhD thesis, Instituto de Biociências, Universidade de São Paulo, São Paulo, Brazil

Metzger JP. 2000. Tree functional group richness and landscape structure in a Brazilian tropical fragmented landscape. *Ecological applications* 10(4): 1147-1161.

Mori SA, Boom BM, Prance GT. 1981. Distribution patterns and conservation of eastern Brazilian coastal forest tree species. *Brittonia* 33(2): 233-245.

Morrone JJ. 2001. Homology, biogeography and areas of endemism. *Diversity and Distributions* 7: 297–300.

Morrone JJ. 1994. On the identification of Areas of Endemism. *Systematic Biology* 43: 438–441.

Negrete L, Lenguas Francavilla M, Damborenea C, Brusa F. 2020. Trying to take over the world: Potential distribution of Obama nungara (Platyhelminthes: Geoplanidae), the Neotropical land planarian that has reached Europe. *Global Change Biology* 26(9): 4907-4918. https://doi.org/10.1111/gcb.15208

Oliveira U, Brescovit AD, Santos AJ. 2015. Delimiting Areas of Endemism through Kernel Interpolation. *PloS ONE*. 10(1): e0116673. https://doi.org/10.1371/journal.pone.0116673 PMID: 25611971

Oliveira U, Soares-Filho B, Leitão RFM, Rodrigues HO. 2019. BioDinamica: a toolkit for analyses of biodiversity and biogeography on the Dinamica-EGO modeling platform. *PeerJ* 7: e7213.

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190(3-4): 231-259.

Pinto-da-Rocha R, DaSilva MB, Bragagnolo C. 2005. Faunistic similarity and historical biogeography of the harvestmen of southern and southeastern Atlantic Rain Forest of Brazil. Journal of Arachnology 33: 290–299.

Platnick NI. 1991. On areas of endemism. *Australian Systematic Botany* 4: 11–12.

Prado JR, Brennand PGG, Godoy LP, Libardi GS, Edson, Abreu F Jr, et al. 2015. Species richness and areas o endemism of oryzomyine rodents (Cricetidae, Sigmodontinae) in South America: an NDM/VNDM approach. *Journal of Biogeography* 42: 540–551.

Radosavljevic A, Anderson RP. 2014. Making better Maxent models of species distributions: complexity, overfitting and evaluation. *Journal of Biogeography* 41(4): 629-643.

Rands MR, Adams WM, Bennun L, Butchart SH, Clements A, Coomes D, …, Vira B. 2010. Biodiversity conservation: challenges beyond 2010. *Science* 329(5997): 1298-1303.

Ravelo AC, Andreasen DH, Lyle M, Lyle AO, Wara MW. 2004. Regional climate shifts caused by gradual global cooling in the Pliocene epoch. *Nature* 429(6989): 263-267.

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation* 142(6): 1141-1153.

Ron SR. 2000. Biogeographic area relationships of lowland Neotropical rainforest based on raw distributions of vertebrate groups. *Biological Journal of the Linnean Society* 71: 379-402.

Saia SEMG, Pessenda LCR, Gouveia SEM, Aravena R, Bendassolli JA. 2008. Last glacial maximum (LGM) vegetation changes in the Atlantic Forest, southeastern Brazil. *Quaternary International* 184: 195–201.

Silva JMC, Sousa MC, Castelletti CHM. 2004. Areas of endemism for passerine birds in the Atlantic forest, South America. *Global Ecology and Biogeography* 13: 85–92.

Silva JLD, Vaz-de-Mello, FZ. 2020. Areas of endemism in the Brazilian Atlantic Forest based on the distribution of dung beetles (Coleoptera, Scarabaeidae, Scarabaeinae). *Iheringia. Série Zoologia* 110.

Sluys R. 1995. Platyhelminths as paleogeographical indicators. *Hydrobiologia* 305(1): 49-53.

Sluys R. 1999. Global diversity of land planarians (Platyhelminthes, Tricladida, Terricola): a new indicator-taxon in biodiversity and conservation studies. *Biodiversity and Conservation* 8: 1663–1681.

Sluys R, Kawakatsu M, Riutort M, Baguñà J. 2009. A new higher classification of planarian flatworms (Platyhelminthes, Tricladida). *Journal of Natural History* 43: 29-30, 1763-1777, DOI: 10.1080/00222930902741669

Sluys R. 2016. Invasion of the flatworms. *American Scientist* 104: 288-295.

Soares-Filho B, Rodrigues H, Follador M. 2013. A hybrid analytical-heuristic method for calibrating land-use change models. *Environmental Modelling & Software* 43:80–87. DOI 10.1016/j.envsoft.2013.01.010.

Szumik C, Casagranda D, Roig-Juñent S. 2006. Manual de NDM/VNDM: programas para la identificación de áreas de endemismo. *Inst. Arg. Est. Filogenet.* 5(3): 1–26.

Szumik C, Cuezzo F, Goloboff PA, Chalup A. 2002. An optimality criterion to determine areas of endemism. *Systematic Biology*. 51: 806–816. https://doi.org/10.1080/10635150290102483 PMID: 12396592

Szumik C, Goloboff PA. 2004. Areas of endemism: an improved optimality criterion. *Systematic Biology.* 53: 968–977. https://doi.org/10.1080/10635150490888859 PMID: 15764564

Tabarelli, M., Aguiar, A. V., Ribeiro, M. C., Metzger, J. P., & Peres, C. A. (2010). Prospects for biodiversity conservation in the Atlantic Forest: lessons from aging human-modified landscapes. *Biological Conservation* 143(10): 2328-2340.

Vane-Wright RI, Humphries CJ, Williams PH. 1991. What to protect?—Systematics and the agony of choice. *Biological Conservation* 55(3): 235-254.

Venne S, Currie DJ. 2021. Can habitat suitability estimated from MaxEnt predict colonizations and extinctions? *Diversity and Distributions* 27(5): 873-886.

Warren DL, Seifert SN. 2011. Ecological niche modeling in Maxent: the importance of model complexity and the performance of model selection criteria. *Ecological Applications* 21(2): 335-342.

Winsor L, Johns PM, Yeates GW. 1998. Introduction, and ecological and systematic background, to the Terricola (Tricladida). *Pedobiologia* 42: 389–404.

Winsor L, Johns PM, Barker GM. 2004. Terrestrial planarians (Platyhelminthes: Tricladida: Terricola) predaceous on terrestrial gastropods. Natural enemies of terrestrial molluscs. Oxfordshire: CAB International 227-278.

Zink RM, Kessen AE, Line TV, Blackwell-Rago RC. 2001. Comparative phylogeography of some arid land bird species. *Condor* 103: 1-10.

Figures

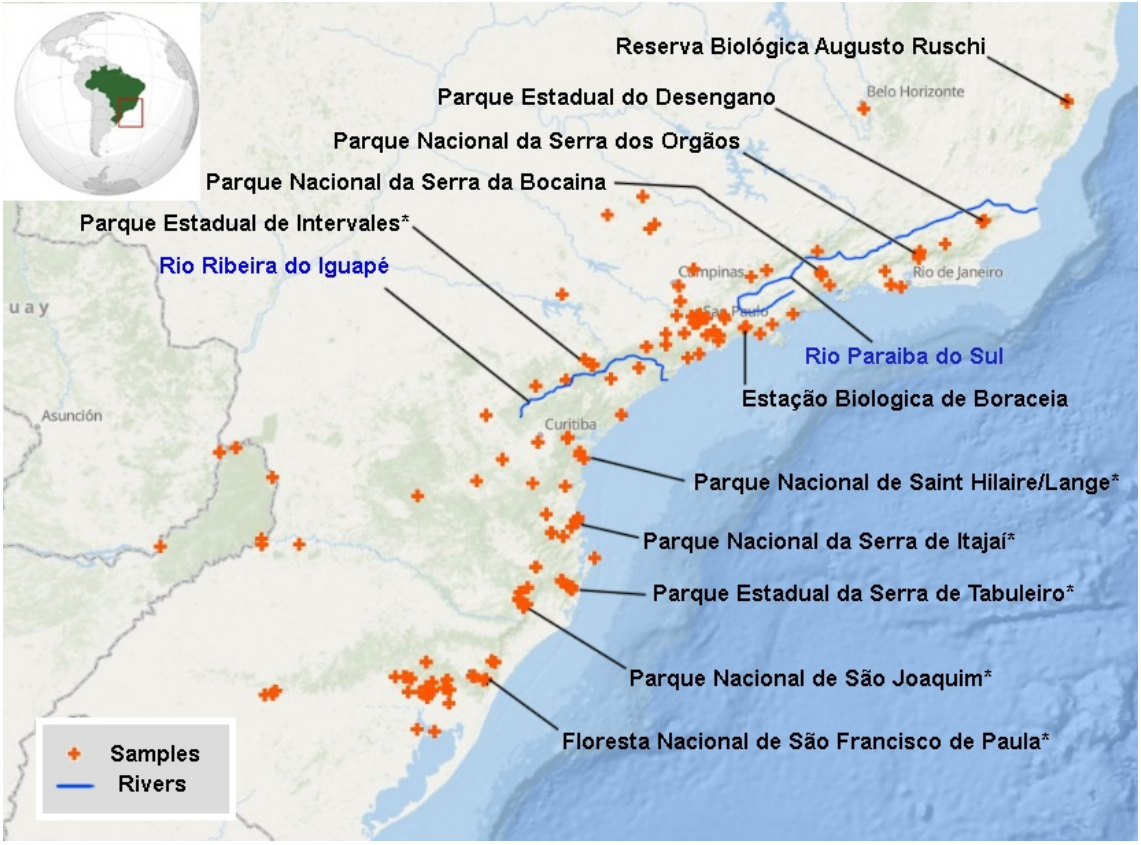


Fig. 1. Localities intensively sampled (~200 person-hour of sampling) in the Atlantic forest (* localities intensively sampled and analysed in Lago-Barcia et al., 2020b). Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.htmlid=30e5fe3149c34df1ba922e6f5bbf808f.

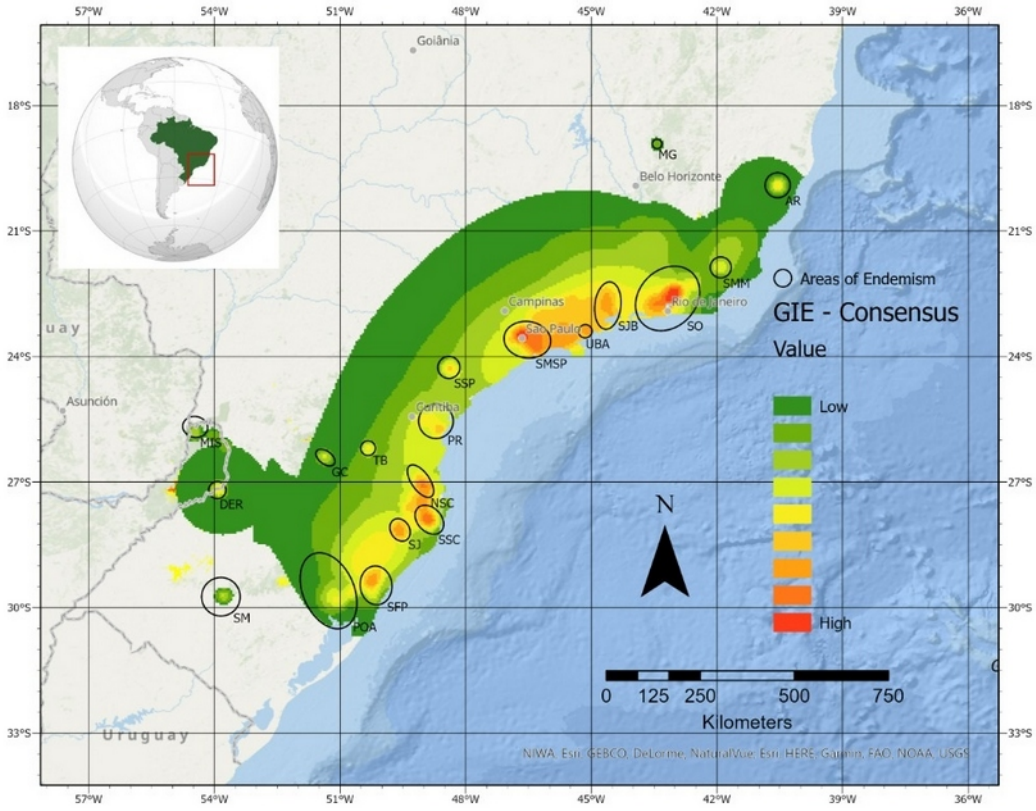


Fig. 2. Geographic Interpolation of Endemism results obtained with six categories, with the predefined weight given by the BioDinamica package (Oliveira et al., 2019) over a topographic map. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

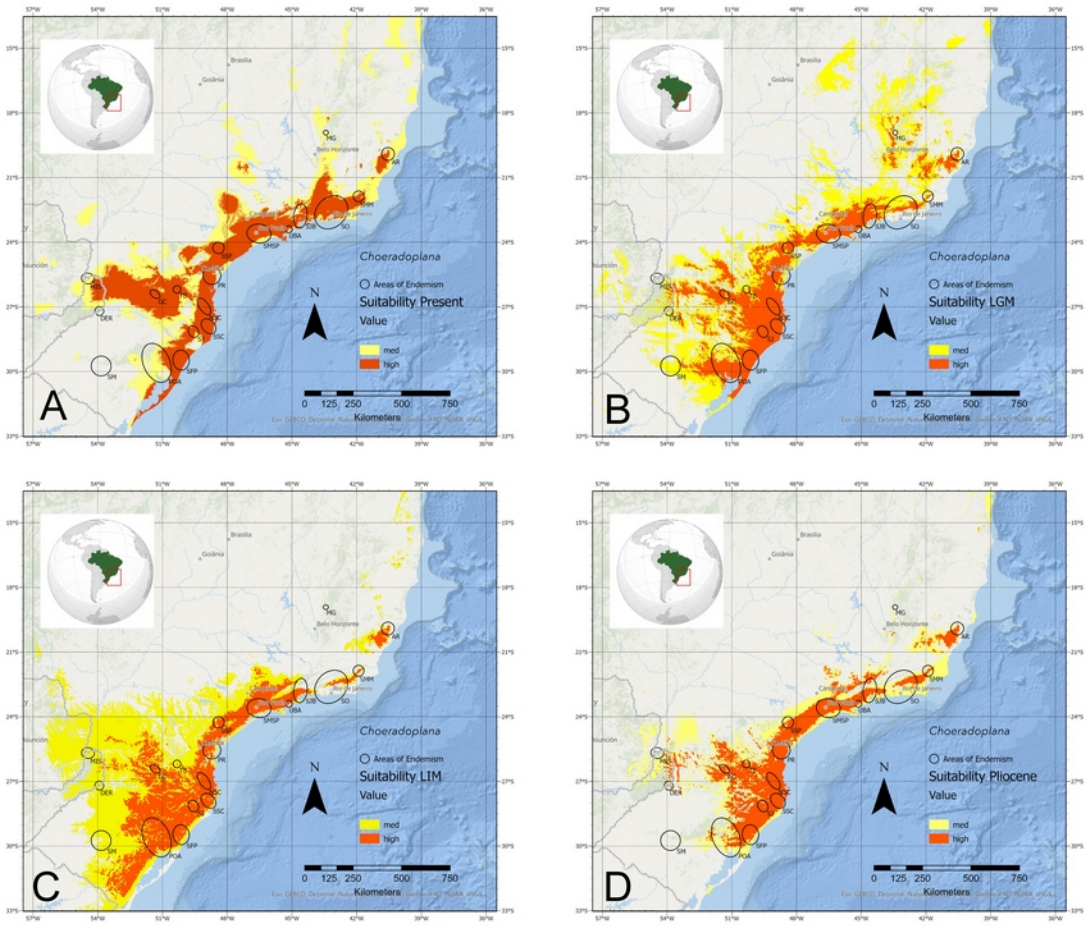


Fig. 3. Niche Models showing suitability areas for species of the genus *Choeradoplana* in, A) the present. B) the Last Glacial Maximum. C) the Last Interglacial Maximum. D) the Mid Pliocene. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

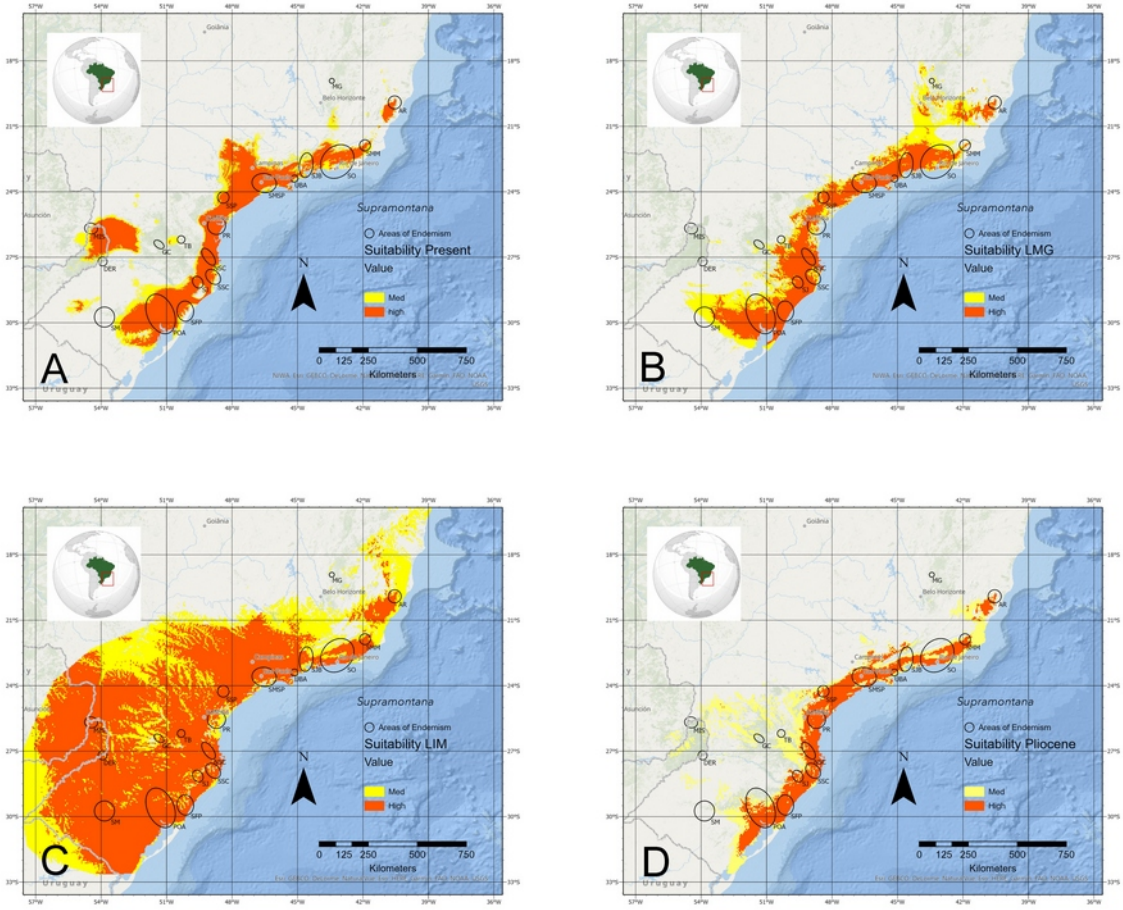


Fig. 4. Niche Models showing suitability areas for species of the genus *Supramontana* in, A) the present. B) the Last Glacial Maximum. C) the Last Interglacial Maximum. D) the Mid Pliocene. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

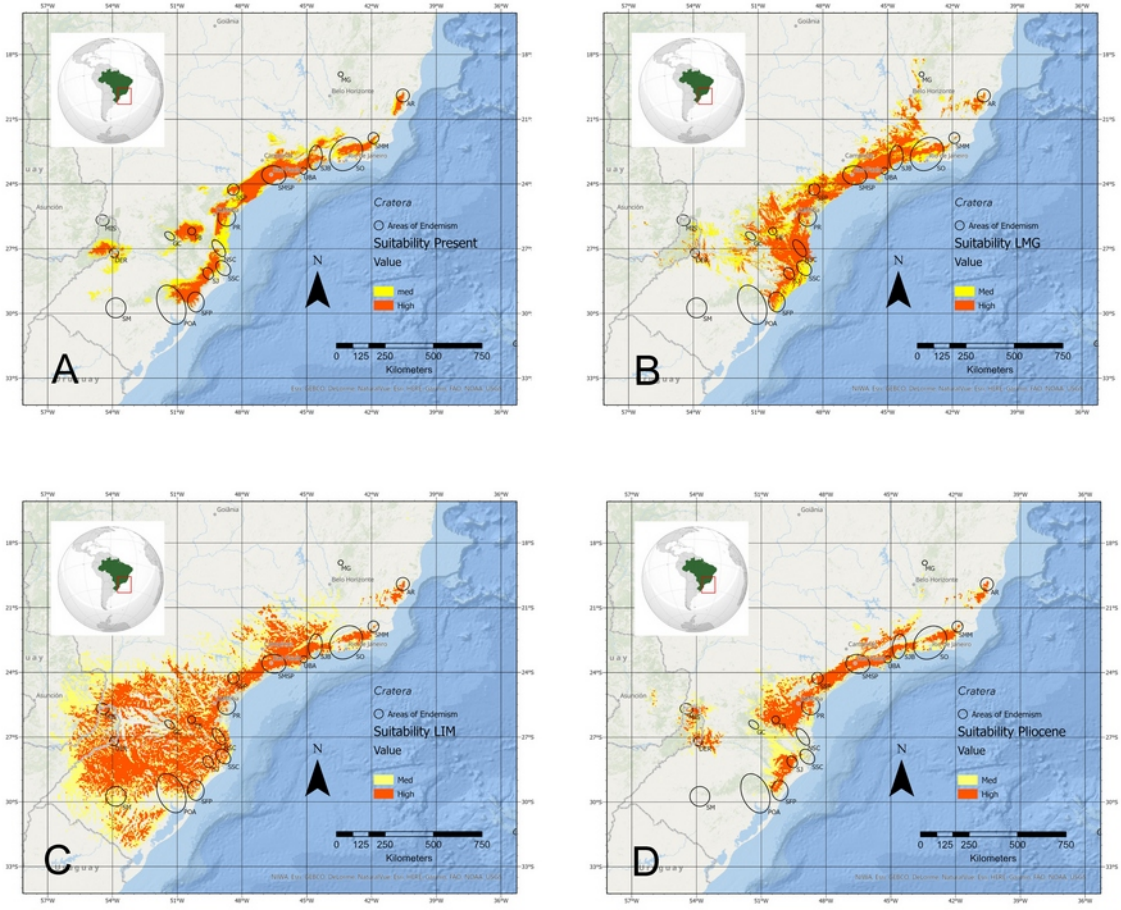
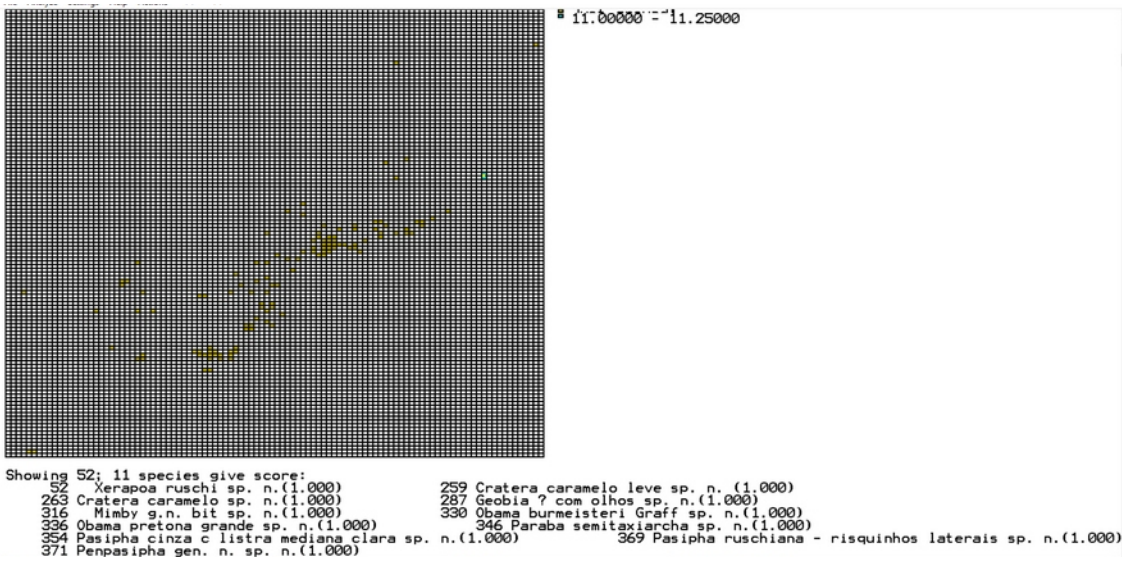
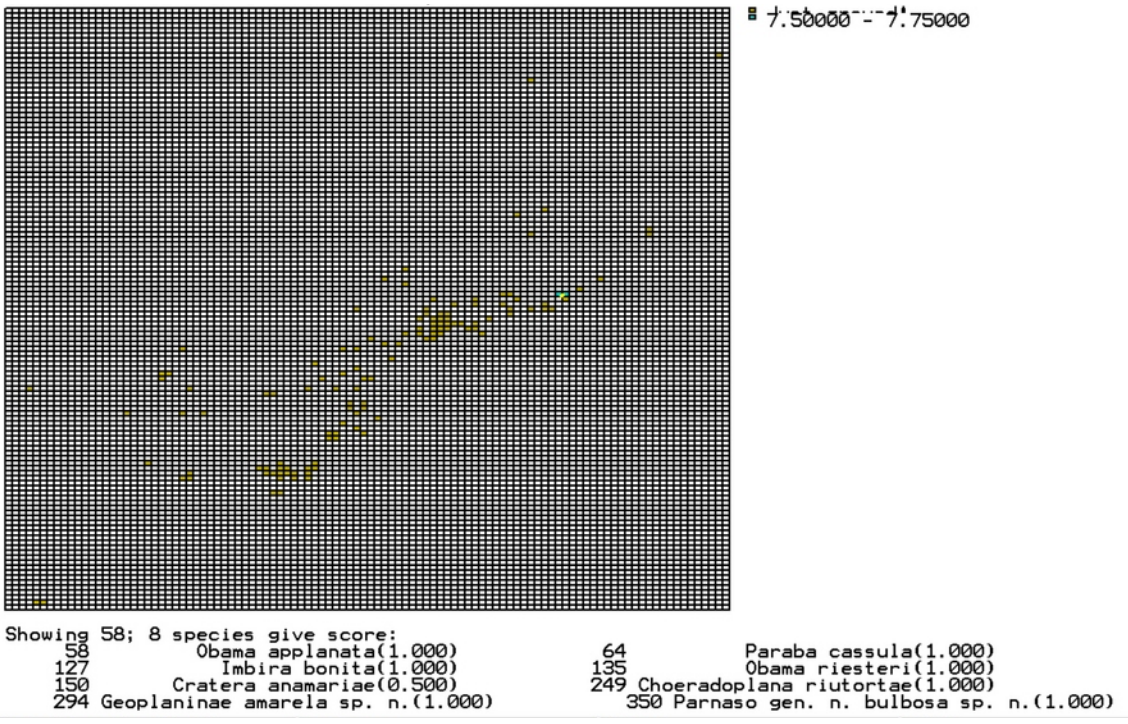


Fig. 5. Niche Models showing suitability areas for species of the genus *Cratera* in, A) the present. B) the Last Glacial Maximum. C) the Last Interglacial Maximum. D) the Mid Pliocene. Basemap source: Esri. "Topographic" [basemap]. Scale Not Given. "World Topographic Map". https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f.

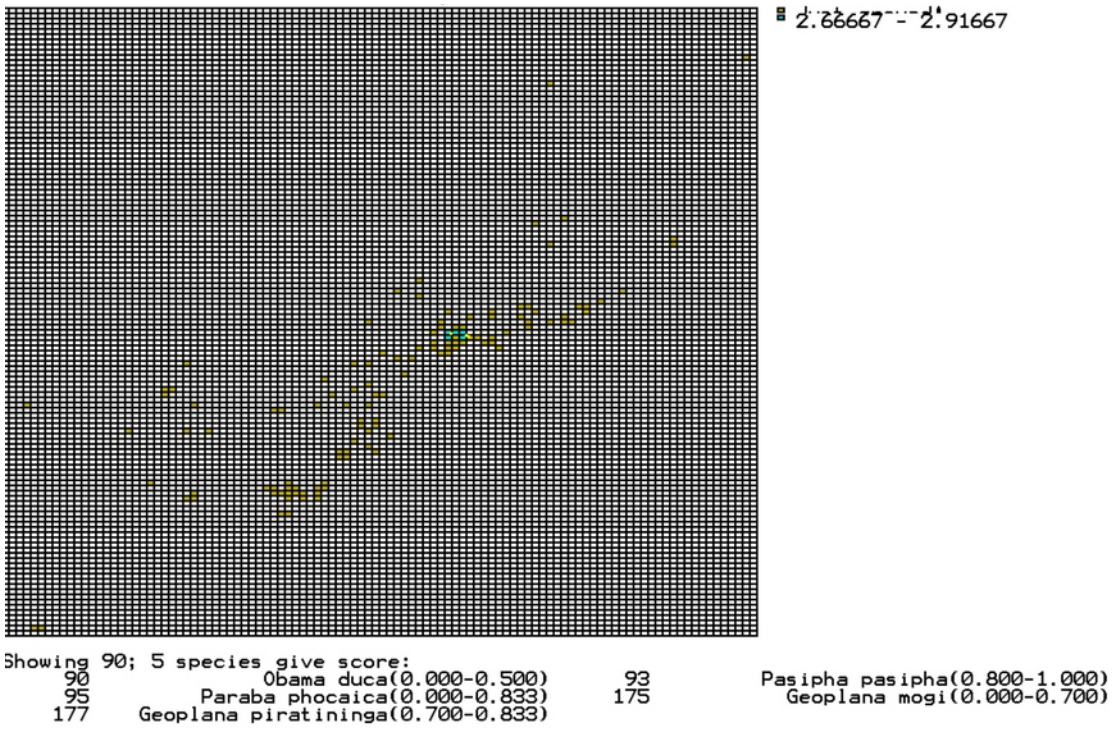
Supplementary Material



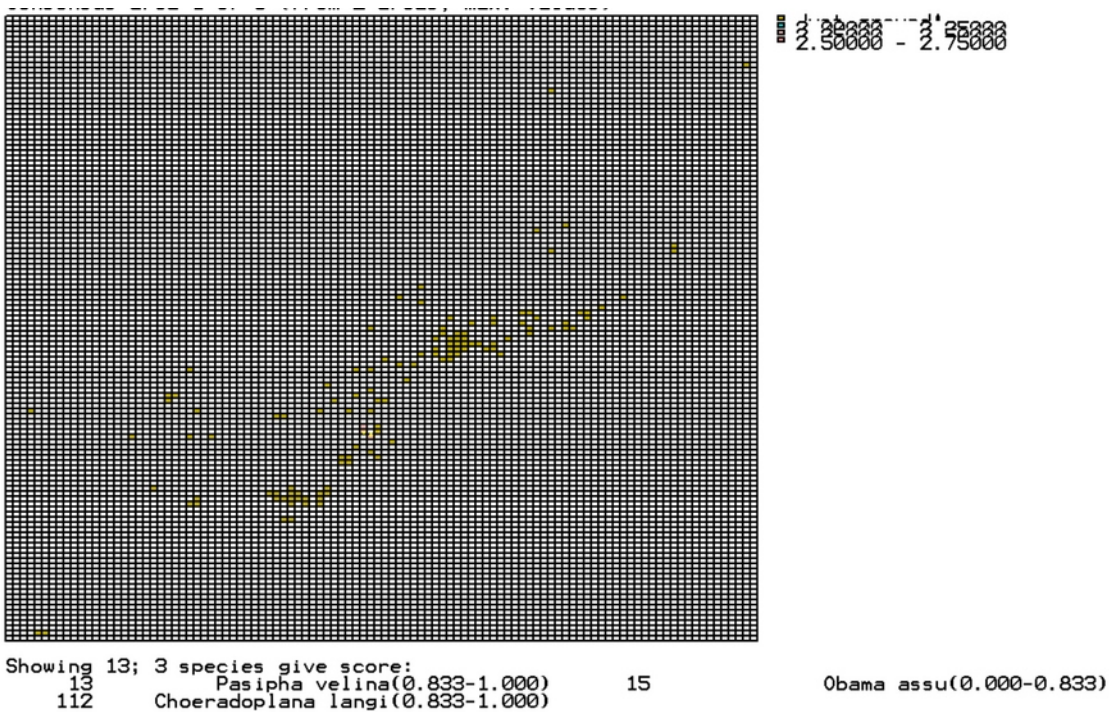
Supp. Fig. 1. AoE Augusto Ruschi (AR) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



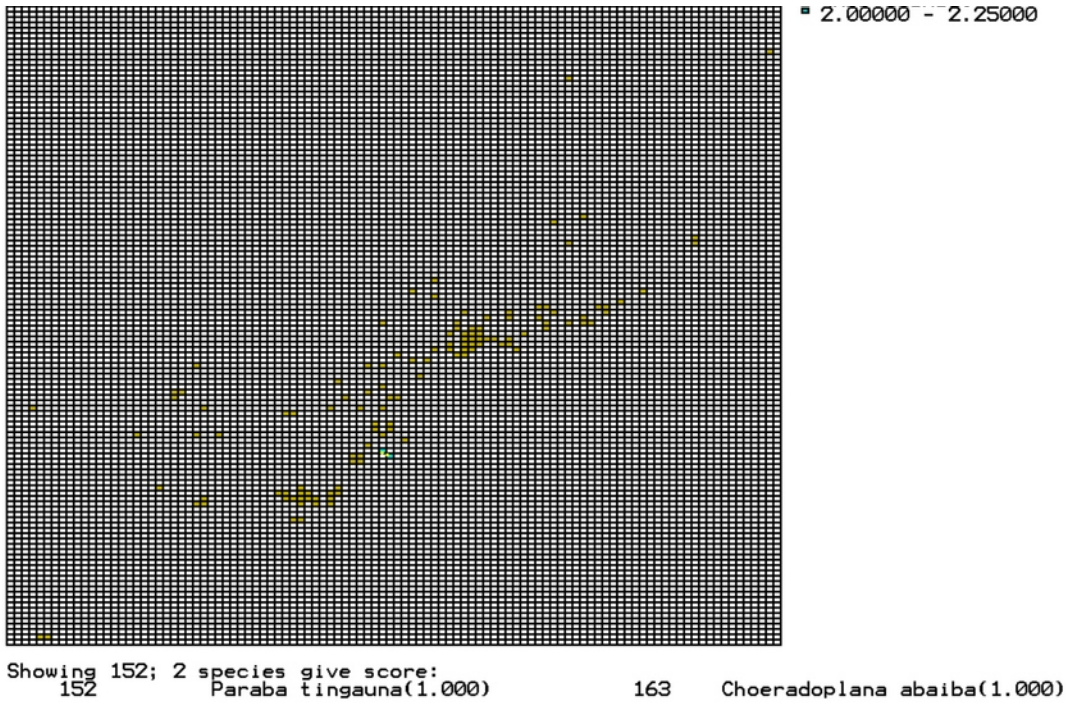
Supp. Fig. 2. AoE Serra dos Orgãos (ORG) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



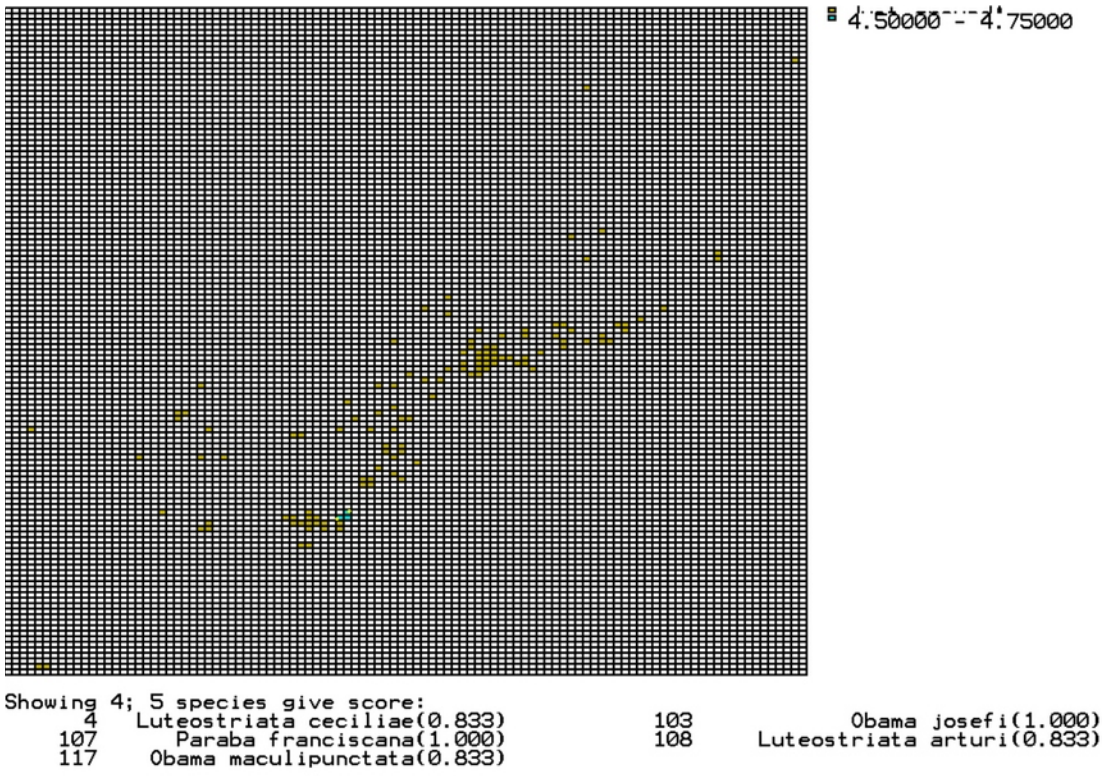
Supp. Fig. 3. AoE Serra do Mar de São Paulo (SMSP) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



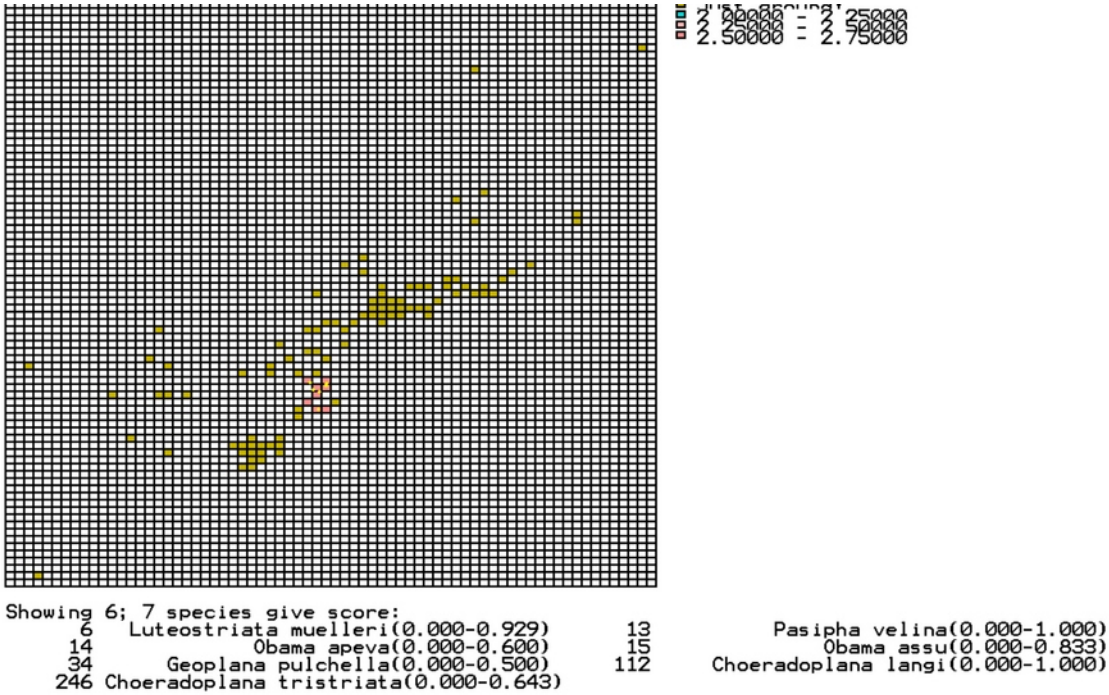
Supp. Fig. 4. AoE North Santa Catarina (NSC) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



Supp. Fig. 5. AoE South Santa Catarina (SSC) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



Supp. Fig. 6. AoE São Francisco de Paula obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.



Supp. Fig. 7. AoE Misiones (MIS) obtained with NDM/VNDM using 0.2º cell size grids. Brown cells represent areas with an Endemicity Score of 0–1.9999 (one or no endemic species found in the cell), blue cells represent areas with an Endemicity Score of 2 or higher (two or more endemic species found in the cell), empty cells represent areas where no sampling was carried out. A list of the endemic species in the area is included.

Supp. Tab. 1. List and geographic coordinates of the species used in the study. Data comes from literature (reference given) and our own unpublished records (a voucher specimen is mentioned as well as the way the specimen was identified). 'Local' refers to the locality the animal was collected, 'Name of sp. in EA' refers to the name of the species in the EA. 'Genus', 'Species' and 'Municipality' to which the specimen belongs and the 'Latitude' and 'Longitude' were it was collected. * arterisk means undescribed species and invalid name.

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F2696	Intervales	sp 0	*Cratera arucuia*	Ribeirão Grande/SP	-24.2693	-48.4054
F2784	Intervales	sp 0	*Cratera arucuia*	Ribeirão Grande/SP	-24.2693	-48.4054
F3094	Intervales	sp 0	*Cratera arucuia*	Ribeirão Grande/SP	-24.2693	-48.4054
Lago-Barcia & Carbayo (2018)		sp 0	*Cratera arucuia*	Ribeirão Grande/SP	-24.2693	-48.4054
Amaral et al 2018		sp 1	*Imbira flavonigra*	Maquiné/RS	-29.501444	-50.221056
Amaral et al 2018		sp 1	*Imbira flavonigra*	Maquiné/RS	-29.501444	-50.221056
Amaral et al 2018		sp 1	*Imbira flavonigra*	Maquiné/RS	-29.501444	-50.221056
F1066	EB Boraceia	sp 10	*Xerapoa pseudorhynchodemus*	Salesópolis	-23.65389	-45.88917
F7086	EcoPark Aruã	sp 10	*Xerapoa pseudorhynchodemus*	Suzano	-23.465563	-46.265396
F7125	EcoPark Aruã	sp 10	*Xerapoa pseudorhynchodemus*	Suzano	-23.465563	-46.265396
F0021	Mata do Instituto de Biociências - USP	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.56566110327161	-46.73040002995005
F1316	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1317	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1318	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1319	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.4965939755	-43.0023684741
F1324	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1327	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1373	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1374	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554	-43.0023684741
F1378	Parnaso	sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis	-22.49659397554616	-43.00236847415091
F1751	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1752	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1767	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1809	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1810	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1892	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F3701	PE Alberto Löfgren	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.462758168233385	-46.63700659481653
F1939	PE Cantareira	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.435798019670848	-46.63520404067118
F3924	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3925	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3927	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3937	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3939	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3942	PE Desengano	sp 10	*Xerapoa*	Santa Maria	-21.87	-41.91

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			pseudorhynchodemus	Madalena		
F3944	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3946	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F3947	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F4053	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F4055	PE Desengano	sp 10	*Xerapoa pseudorhynchodemus*	Santa Maria Madalena	-21.87	-41.91
F6796	PE Pedra Branca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.93720	-043.46122
F1117	PN Itatiaia - Km 08 - Sítio Piporaoca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.4744673237292	-44.5798137567613
F6241	PN Tijuca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.95668	-43.27949
F6256	PN Tijuca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6309	PN Tijuca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6310	PN Tijuca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6346	PN Tijuca	sp 10	*Xerapoa pseudorhynchodemus*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F1152	Pq da Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.579662	-46.727503
F4681	Pq da Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.579662	-46.727503
F4684	Pq da Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.579662	-46.727503
F0033A~F0021	Pq Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.580206	-46.727321
F0033B~F0021	Pq Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.580206	-46.727321
F0033C	Pq Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.580206	-46.727321
F0033D~F0021	Pq Previdência	sp 10	*Xerapoa pseudorhynchodemus*	São Paulo	-23.580206	-46.727321
F2244	RB Ruschi	sp 10	*Xerapoa pseudorhynchodemus*	Santa Teresa	-19.88	-40.54
Froehlich (1959)		sp 10	*Xerapoa pseudorhynchodemus*	Blumenau/SC	-27.05386	-49.08606
Lago-Barcia et al., 2020 / F3350		sp 10	*Xerapoa pseudorhynchodemus*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F1465		sp 10	*Xerapoa pseudorhynchodemus*	PNItajai	-27.05306	-49.08528
Lago-Barcia et al., 2020 / F1708		sp 10	*Xerapoa pseudorhynchodemus*	Saint-Hilaire	-25.469604	-48.813739
Marcus (1951)		sp 10	*Xerapoa pseudorhynchodemus*	São Paulo/SP	-23.500212	-46.702310
Riester (1938)		sp 10	*Xerapoa pseudorhynchodemus*	Teresópolis/RJ	-22.439089	-42.994351
Amaral & Leal-Zanchet (2016)		sp 100	*Pasipha mesoxantha*	Santa Maria/RS	-29.722778	-53.714177
Amaral & Leal-Zanchet (2016)		sp 100	*Pasipha mesoxantha*	Santa Maria/RS	-29.722778	-53.714177
Amaral & Leal-Zanchet (2016)	State Park of Turvo	sp 101	*Pasipha turvensis*	Derrubadas/RS	-27.247305	-53.893789
Amaral & Leal-Zanchet (2016)	State Park of Turvo	sp 101	*Pasipha turvensis*	Derrubadas/RS	-27.247305	-53.893789
F3033-	PE Cantareira	sp 102	*Luteostriata ernesti*	São Paulo	-23.42	-46.63
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	Curitiba/PR	-25.548339	-49.313845
Carbayo (2010)		sp 102	*Luteostriata ernesti*	Ibiúna/SP	-23.75	-47.19
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	Jundiaí/SP	-23.21	-46.95
Carbayo (2010)		sp 102	*Luteostriata ernesti*	Mogi das Cruzes/SP	-23.505856	-46.211903
Lago-Barcia et al., 2020 / F3222		sp 102	*Luteostriata ernesti*	PE Tabuleiro	-27.94	-48.79
Carbayo (2010)		sp 102	*Luteostriata ernesti*	Pirassununga/SP	-22.007522	-47.459448
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	Ribeirão Pires/SP	-23.701329	-46.39
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	São Paulo/SP	-23.453148	-46.634488
Leal-Zanchet & Froehlich (2006)		sp 102	*Luteostriata ernesti*	Valinhos/SP	-22.96	-46.98
Baptista et al (2006)		sp 103	*Obama josefi*	Cambará do Sul/RS	-29.179104	-50.080631
Carbayo & Leal-		sp 103	*Obama josefi*	São Francisco de	-29.428944	-50.392000

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Zanchet (2001)				Paula/RS		
Leal-Zanchet et al (2011)		sp 103	*Obama josefi*	São Francisco de Paula/RS	-29.179104	-50.080631
Leal-Zanchet et al (2011)		sp 103	*Obama josefi*	São Francisco de Paula/RS	-29.480590	-50.174679
Baptista et al (2006)		sp 104	*Luteostriata graffi*	Cambará do Sul/RS	-29.179104	-50.080631
Almeida et al (2018)		sp 104	*Luteostriata graffi*	Florianópolis/SC	-27.468485	-48.377724
Carbayo (2010)		sp 104	*Luteostriata graffi*	Morro Reuter/RS	-29.53	-51.07
Carbayo (2010)		sp 104	*Luteostriata graffi*	Parobé/RS	-29.62940	-50.83110
Leal-Zanchet & Froehlich (2006)		sp 104	*Luteostriata graffi*	Salvador do Sul/RS	-29.442428	-51.502151
Antunes et al (2012)		sp 104	*Luteostriata graffi*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2011)		sp 104	*Luteostriata graffi*	São Francisco de Paula/RS	-29.480590	-50.174679
Leal-Zanchet & Froehlich (2006)		sp 104	*Luteostriata graffi*	Taquara/RS	-29.659801	-50.779542
Leal-Zanchet & Froehlich (2006)		sp 104	*Luteostriata graffi*	Três Coroas/RS	-29.49	-50.82
Carbayo & Leal-Zanchet (2003)		sp 105	*Supramontana irritata*	São Francisco de Paula/RS	-29.428944	-50.392000
Carbayo & Leal-Zanchet (2003)		sp 105	*Supramontana irritata*	São Francisco de Paula/RS	-29.428944	-50.392000
Carbayo & Leal-Zanchet (2003)		sp 105	*Supramontana irritata*	São Francisco de Paula/RS	-29.428944	-50.392000
Carbayo & Leal-Zanchet (2003)		sp 105	*Supramontana irritata*	São Francisco de Paula/RS	-29.428944	-50.392000
Baptista et al (2010)		sp 106	*Paraba rubidolineata*	Derrubadas/RS	-27.247305	-53.893789
Lago-Barcia et al., 2020 / F3271		sp 106	*Paraba rubidolineata*	PE Tabuleiro	-27.840735	-48.924866
Baptista & Leal-Zanchet (2005)		sp 106	*Paraba rubidolineata*	São Francisco de Paula/RS	-29.428944	-50.392000
Baptista et al (2006)		sp 107	*Paraba franciscana*	Cambará do Sul/RS	-29.179104	-50.080631
Leal-Zanchet & Carbayo (2001)		sp 107	*Paraba franciscana*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2011)		sp 107	*Paraba franciscana*	São Francisco de Paula/RS	-29.480590	-50.174679
Leal-Zanchet et al (2011)		sp 108	*Luteostriata arturi*	Cambará do Sul/RS	-29.179104	-50.080631
Lemos & Leal-Zanchet (2008)		sp 108	*Luteostriata arturi*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 109	*Pasipha backesi*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 109	*Pasipha backesi*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 109	*Pasipha backesi*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 109	*Pasipha backesi*	São Francisco de Paula/RS	-29.428944	-50.392000
F5880	EcoPark Aruã	sp 11	*"Geoplana" quagga*	Mogi das Cruzes	-23.46273	-46.26598
F5913	EcoPark Aruã	sp 11	*"Geoplana" quagga*	Mogi das Cruzes	-23.46426	-46.26573
F6663	Fazenda Loanda, terreno baldio	sp 11	*"Geoplana" quagga*	Bananal	-22.678586	-44.225681
F1323	Parnaso	sp 11	*"Geoplana" quagga*	Teresópolis	-22.49659397554616	-43.00236847415091
F2598	Parnaso	sp 11	*"Geoplana" quagga*	Teresópolis	-22.455277777777777	-42.9975
F2599	Parnaso	sp 11	*"Geoplana" quagga*	Teresópolis	-22.455277777777777	-42.9975
F1822	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1824	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1829	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1833	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1916	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1933	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F1934	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F3691	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F3700	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F3702	PE Alberto Löfgren	sp 11	*"Geoplana" quagga*	São Paulo	-23.462758168233385	-46.63700659481653
F2875	PE Cantareira	sp 11	*"Geoplana" quagga*	São Paulo	-23.460277777777776	-46.63666666666666

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F6742	PE Pedra Branca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.93430	-043.45087
F1119	PN Itatiaia - Km 08 - Sítio Piporaoca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.4744673237292	-44.5798137567613
F6290	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6292	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6312	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6313	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6319	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6320	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6321	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6327	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6329	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6330	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6332	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6334	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6336	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6340	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6344	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6347	PN Tijuca	sp 11	*"Geoplana" quagga*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F1178	Pq da Previdência	sp 11	*"Geoplana" quagga*	São Paulo	-23.580230	-46.727515
F4682	Pq da Previdência	sp 11	*"Geoplana" quagga*	São Paulo	-23.579662	-46.727503
F6354	Pq da Previdência	sp 11	*"Geoplana" quagga*	São Paulo	-23.579662	-46.727503
F1032	Sítio Prof. Menna	sp 11	*"Geoplana" quagga*	Mogi das Cruzes	-23.451536	-46.227993
F1079	Sítio Prof. Menna	sp 11	*"Geoplana" quagga*	Mogi das Cruzes	-23.451536	-46.227993
Froehlich (1959)		sp 11	*"Geoplana" quagga*	Blumenau/SC	-27.05386	-49.08606
Marcus (1951)		sp 11	*"Geoplana" quagga*	São Paulo/SP	-23.577633	-46.701739
CG Froehlich (1956a)		sp 11	*"Geoplana" quagga*	Teresópolis/RJ	-22.439089	-42.994351
Marcus, 1951	Horto florestal	sp 11	*“Geoplana” quagga*	São Paulo	-23.45565259401509	-46.637007330822264
Leal-Zanchet et al (2012)		sp 110	*Pasipha brevilineata*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 110	*Pasipha brevilineata*	São Francisco de Paula/RS	-29.428944	-50.392000
Leal-Zanchet et al (2012)		sp 110	*Pasipha brevilineata*	São Francisco de Paula/RS	-29.428944	-50.392000
Lemos & Leal-Zanchet (2008)		sp 111	*Luteostriata pseudoceciliae*	São Francisco de Paula/RS	-29.428944	-50.392000
Graff (1899)		sp 112	*Choeradoplana langi*	Blumenau/SC	-27.05386	-49.08606
du Bois Reymond-Marcus (1951)		sp 112	*Choeradoplana langi*	Brusque/SC	-27.111325	-48.895427
Lago-Barcia et al., 2020 / F3590		sp 113	*Cratera sp. 3*	Saint-Hilaire	-25.469604	-48.813739
Hyman (1955)		sp 114	*Obama catharina*	São Bento do Sul/SC	-26.23	-49.40
Rossi et al (2014)		sp 115	*Cratera steffeni*	Cambará do Sul/RS	-29.179104	-50.080631
Lago-Barcia et al., 2020 / F7267		sp 116	*Cratera ochra*	PN São Joaquim	-28.157565	-49.638002
Rossi et al (2016)		sp 116	*Cratera ochra*	São Francisco de Paula/RS	-29.428944	-50.392000
Rossi et al (2016)		sp 117	*Obama maculipunctata*	Praia Grande/SC	-29.198086	-50.026672
Rossi et al (2016)		sp 117	*Obama maculipunctata*	São Francisco de Paula/RS	-29.428944	-50.392000
Rossi & Leal-Zanchet (2017)		sp 118	*Cratera nigrimarginata*	General Carneiro/PR	-26.44	-51.31
Rossi & Leal-Zanchet (2017)		sp 119	*Cratera cryptolineata*	Três Barras/SC	-26.19	-50.33
F1942	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.435798019670848	-46.63520404067118
F1943	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.435798019670848	-46.63520404067118
F1944	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.435798019670848	-46.63520404067118
F1947	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.435798019670848	-46.63520404067118
F2872	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2873	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2874	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2876	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2878	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2880	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2881	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F2882	PE Cantareira	sp 12	*Pasipha tapetilla*	São Paulo	-23.460277777777776	-46.63666666666666
F1149	Pq da Previdência	sp 12	*Pasipha tapetilla*	São Paulo	-23.579662	-46.727503
F2298	RB Ruschi	sp 12	*Pasipha tapetilla*	Santa Teresa	-19875	-40.53527777777778
F2301	RB Ruschi	sp 12	*Pasipha tapetilla*	Santa Teresa	-19875	-40.53527777777778
F2303	RB Ruschi	sp 12	*Pasipha tapetilla*	Santa Teresa	-19875	-40.53527777777778
F2304	RB Ruschi	sp 12	*Pasipha tapetilla*	Santa Teresa	-19875	-40.53527777777778
F2306	RB Ruschi	sp 12	*Pasipha tapetilla*	Santa Teresa	-19875	-40.53527777777778

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Froehlich (1959)		sp 12	*Pasipha tapetilla*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 12	*Pasipha tapetilla*	Itajaí/SC	-26.957485	-48.756133
Lago-Barcia et al., 2020 / F3201		sp 12	*Pasipha tapetilla*	PE Tabuleiro	-27.94	-48.79
Marcus, 1951		sp 12	*Pasipha tapetilla*	Pirassununga	-22.00377495649689	-47.434988437672025
Marcus (1951)		sp 12	*Pasipha tapetilla*	Pirassununga/SP	-22.007522	-47.459448
Lago-Barcia et al., 2020 / F1405		sp 12	*Pasipha tapetilla*	PNItajai	-27.05306	-49.08528
CG Froehlich (1956a)		sp 12	*Pasipha tapetilla*	Rio de Janeiro/RJ	-22.975852	-43.292230
Carbayo et al (2013)		sp 12	*Pasipha tapetilla*	São Paulo/SP	-23.46047	-46.63672
CG Froehlich (1956a)		sp 12	*Pasipha tapetilla*	Teresópolis/RJ	-22.500057	-42.997365
CG Froehlich (1956a)		sp 12	*Pasipha tapetilla*	Ubatuba/SP	-23.423381	-45.083399
Rossi & Leal-Zanchet (2017)		sp 120	*Cratera aureomaculata*	Três Barras/SC	-26.19	-50.33
F1076	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F1077	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F2119	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F2142	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F2144	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F2145	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F4144	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F4145	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F4146	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F4169	EB Boraceia	sp 121	*Obama itatiayana*	Salesópolis	-23.65389	-45.88917
F6657	Fazenda Loanda, terreno baldio	sp 121	*Obama itatiayana*	Bananal	-22.678565	-44.225643
F6661	Fazenda Loanda, terreno baldio	sp 121	*Obama itatiayana*	Bananal	-22.678586	-44.225681
F5148	PN Itatiaia	sp 121	*Obama itatiayana*	Resende	-22.454444444444444	-44.60777777777778
F1115	PN Itatiaia - Km 08 - Sítio Piporaoca	sp 121	*Obama itatiayana*	Rio de Janeiro	-22.4744673237292	-44.5798137567613
Schirch (1929)		sp 121	*Obama itatiayana*	Resende/RJ	-22.38	-44.68
Schultze & Müller (1857)		sp 122	*Notogynaphallia octostriata*	Blumenau/SC	-27.05386	-49.08606
Graff (1899)		sp 122	*Notogynaphallia octostriata*	Morro Reuter/RS	-29.53	-51.07
F3991	PE Desengano	sp 123	*Choeradoplana albonigra*	Santa Maria Madalena	-21.87	-41.91
F4024	PE Desengano	sp 123	*Choeradoplana albonigra*	Santa Maria Madalena	-21.87	-41.91
F4031	PE Desengano	sp 123	*Choeradoplana albonigra*	Santa Maria Madalena	-21.87	-41.91
F4081	PE Desengano	sp 123	*Choeradoplana albonigra*	Santa Maria Madalena	-21.87	-41.91
F4092	PE Desengano	sp 123	*Choeradoplana albonigra*	Santa Maria Madalena	-21.87	-41.91
F2313	RB Ruschi	sp 123	*Choeradoplana albonigra*	Santa Teresa	-19875	-40.53527777777778
F2391	RB Ruschi	sp 123	*Choeradoplana albonigra*	Santa Teresa	-19875	-40.53527777777778
Carbayo et al (2017)		sp 123	*Choeradoplana albonigra*	Santa Maria Madalena/RJ	-21.90	-41.95
Carbayo et al (2017)		sp 123	*Choeradoplana albonigra*	Santa Teresa/ES	-19.90	-40.54
Riester (1938)		sp 123	*Choeradoplana albonigra*	Teresópolis/RJ	-22.439089	-42.994351
Riester (1938)		sp 124	*Pasipha biseminalis*	Teresópolis/RJ	-22.439089	-42.994351
Lago-Barcia et al., 2020 / F3582		sp 125	*Cratera sp. 2*	Saint-Hilaire	-25.469604	-48.813739
Riester (1938)		sp 126	*Pasipha caeruleonigra*	Teresópolis/RJ	-22.439089	-42.994351
F1249	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.4482	-42.9834
F1263	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.4482	-42.9834
F1268	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.4482	-42.9834
F1269	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.4482	-42.9834
F1277	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1278	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1279	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1280	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1281	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1282	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1283	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1284	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1285	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1286	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1287	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F1288	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1289	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1290	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1291	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1292	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1293	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1294	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1295	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1296	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1297	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1298	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1299	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1300	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1301	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1302	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1303	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1305	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1306	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1307	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1310	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1313	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.47219469581555	-43.055074298022454
F1338	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1339	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1340	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1342	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1343	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1346	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1347	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1348	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1349	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1351	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1352	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F1363	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.49659397554616	-43.00236847415091
F2615	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.455277777777777	-42.9975
F2616	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.455277777777777	-42.9975
F2617	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.455277777777777	-42.9975
F2618	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.455277777777777	-42.9975
F4202	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45638888888889	-42995
F4225	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4226	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4227	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4228	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4229	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4230	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4231	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4232	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4233	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4234	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4235	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4236	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4237	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4238	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4239	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4240	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4241	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4242	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4243	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4244	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4245	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4246	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4247	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4248	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4257	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4259	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4270	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4271	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4272	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4277	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4279	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4280	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4284	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4287	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4289	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4297	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45138888888889	-43.00138888888889
F4312	Parnaso	sp 127	*Imbira bonita*	Teresópolis	-22.45642	-42.99514
Riester (1938)		sp 127	*Imbira bonita*	Teresópolis/RJ	-22.439089	-42.994351
F1906	PE Alberto Löfgren	sp 128	*Alberta gen. n. cafusita* *	São Paulo	-23.462758168233385	-46.63700659481653
F3688	PE Alberto Löfgren	sp 128	*Alberta gen. n. cafusita* *	São Paulo	-23.462758168233385	-46.63700659481653
F3724	PE Cantareira	sp 128	*Alberta gen. n. cafusita*	São Paulo	-23.451890	-46.637104

Field Code nº or Reference	Local	Name of sp. in EA	Species *	Municipality	Latitude (decimal)	Longitude (decimal)
Riester (1938)		sp 129	*Pasipha velutina*	Nova Lima/MG	-20.02	-43.91
Froehlich (1959)		sp 13	*Pasipha velina*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 13	*Pasipha velina*	Brusque/SC	-27.111325	-48.895427
Riester (1938)		sp 130	*Paraba incognita*	Teresópolis/RJ	-22.439089	-42.994351
F4183	Parnaso	sp 131	*Obama eudoxiae*	Teresópolis	-22.45638888888889	-42995
F4210	Parnaso	sp 131	*Obama eudoxiae*	Teresópolis	-22.45638888888889	-42995
F4313	Parnaso	sp 131	*Obama eudoxiae*	Teresópolis	-22.45642	-42.99514
Riester (1938)		sp 131	*Obama eudoxiae*	Teresópolis/RJ	-22.439089	-42.994351
Riester (1938)		sp 132	*Obama dictyonota*	Teresópolis/RJ	-22.439089	-42.994351
Riester (1938)		sp 133	*Obama notophthalma*	Nova Lima/MG	-20.02	-43.91
Riester (1938)		sp 133	*Obama notophthalma*	Teresópolis/RJ	-22.439089	-42.994351
F1330	Parnaso	sp 134	*Obama eudoximariae*	Teresópolis	-22.49659397554616	-43.00236847415091
F2602	Parnaso	sp 134	*Obama eudoximariae*	Teresópolis	-22.455277777777777	-42.9975
F4065	PE Desengano	sp 134	*Obama eudoximariae*	Santa Maria Madalena	-21.87	-41.91
F6447	PE Pedra Branca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.95681	-43.44840
F6480	PE Pedra Branca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.93738	-43.46145
F6489	PE Pedra Branca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.93738	-43.46145
F6815	PE Pedra Branca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.93369	-043.45074
F6824	PE Pedra Branca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.93581	-043.45752
F7890	PN Tijuca	sp 134	*Obama eudoximariae*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
Riester (1938)		sp 134	*Obama eudoximariae*	Teresópolis/RJ	-22.500057	-42.997365
F1127	Parnaso	sp 135	*Obama riesteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1128	Parnaso	sp 135	*Obama riesteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1341	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.49659397554616	-43.00236847415091
F2560	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.455277777777777	-42.9975
F2577	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.455277777777777	-42.9975
F2591	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.455277777777777	-42.9975
F2592	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.455277777777777	-42.9975
F2625	Parnaso	sp 135	*Obama riesteri*	Teresópolis	-22.455277777777777	-42.9975
Riester, 1938		sp 135	*Obama riesteri*	Teresópolis	-22.431959888773907	-43.005162984271685
F2550	Parnaso	sp 136	*Obama fryi*	Teresópolis	-22.455277777777777	-42.9975
F2554	Parnaso	sp 136	*Obama fryi*	Teresópolis	-22.455277777777777	-42.9975
F2586	Parnaso	sp 136	*Obama fryi*	Teresópolis	-22.455277777777777	-42.9975
Graff (1899)		sp 136	*Obama fryi*	Rio de Janeiro/RJ	-22.975852	-43.292230
Riester (1938)		sp 136	*Obama fryi*	Teresópolis/RJ	-22.500057	-42.997365
Negrete & Brusa (2014)		sp 137	*Choeradoplana crassiphalla*	San Antonio/Arg	-26.132969	-53.716113
Lago-Barcia et al., 2020 / F2694		sp 138	*Cratera sp. 1*	PE Intervales	-24.269387	-48.405467
Negrete & Brusa (2016)		sp 139	*Cratera viridimaculata*	San Antonio/Arg	-26.132969	-53.716113
Lago-Barcia et al., 2020 / F6512		sp 14	*Obama apeva*	Alfredo Wagner/SC	-27.61727	-49.35075
Froehlich (1959)		sp 14	*Obama apeva*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 14	*Obama apeva*	Brusque/SC	-27.111325	-48.895427
Lago-Barcia et al., 2020 / F3287		sp 14	*Obama apeva*	PE Tabuleiro	-27.840735	-48.924866
Negrete et al (2014)		sp 140	*Supramontana argentina*	San Antonio/Arg	-25.638105	-54.324086
Negrete et al (2014)		sp 140	*Supramontana argentina*	San Antonio/Arg	-26.132969	-53.716113
Negrete & Brusa (2016)	San Antonio Strict Nature Reserve	sp 141	*Pasipha atla*	San Antonio/Arg	-26.132969	-53.716113
Negrete & Brusa (2016)	Urugua-í Wildlife Reserve,	sp 141	*Pasipha atla*	Misiones	-25.867135298410876	-54.463605271
Negrete & Brusa (2016)	Urugua-í Wildlife Reserve,	sp 141	*Pasipha atla*	Misiones	-25.867135298410876	-54.463605271
Negrete & Brusa (2016)		sp 142	*Pasipha johnsoni*	Misiones	-25.867135298410876	-54.463605271
Negrete & Brusa (2016)		sp 142	*Pasipha johnsoni*	Misiones	-25.867135298410876	-54.463605271
Negrete & Brusa (2016)		sp 143	*Pasipha mbya*	Misiones	-25.867135298410876	-54.463605271
Negrete & Brusa (2016)		sp 143	*Pasipha mbya*	Misiones	-25.682442302746164	-54.4575180271
F5892	EcoPark Aruã	sp 144	*Choeradoplana banga*	Mogi das Cruzes	-23.46393	-46.26587
F7115	EcoPark Aruã	sp 144	*Choeradoplana banga*	Suzano	-23.465563	-46.265396
F2023	PE Cantareira	sp 144	*Choeradoplana banga*	São Paulo	-23.435798019670848	-46.63520404067118
F2948	PE Cantareira	sp 144	*Choeradoplana banga*	São Paulo	-23.42	-46.63
F3006	PE Cantareira	sp 144	*Choeradoplana banga*	São Paulo	-23.42	-46.63

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F3011	PE Cantareira	sp 144	*Choeradoplana banga*	São Paulo	-23.42	-46.63
F3521	PE Cantareira	sp 144	*Choeradoplana banga*	São Paulo	-23.42	-46.63
F5177	PN Itatiaia	sp 144	*Choeradoplana banga*	Resende	-22.454444444444444	-44.60777777777778
Carbayo et al (2017)		sp 144	*Choeradoplana banga*	Campos do Jordão/SP	-22.70	-45.52
Carbayo & Froehlich (2012)		sp 144	*Choeradoplana banga*	São Paulo/SP	-23.45	-46.63
F3494	SFP	sp 145	*Choeradoplana benyai*	São Francisco de Paula	-29.436278	-50.373694
Lago-Barcia et al., 2020 / F3813	Tabuleiro	sp 145	*Choeradoplana benyai*	São Bonifácio	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F3813		sp 145	*Choeradoplana benyai*	PE Tabuleiro	-27.86	-48.91
Carbayo et al (2017)		sp 145	*Choeradoplana benyai*	São Francisco de Paula/RS	-29.42	-50.39
F2104	PN Bocaina	sp 146	*Choeradoplana bocaina*	São José do Barreiro	-22.7501	-44.6208
F2803	PN Bocaina	sp 146	*Choeradoplana bocaina*	São José do Barreiro	-22.7501	-44.6208
F2822	PN Bocaina	sp 146	*Choeradoplana bocaina*	São José do Barreiro	-22.7501	-44.6208
Carbayo & Froehlich (2012)		sp 146	*Choeradoplana bocaina*	São José do Barreiro/SP	-22.75	-44.62
Carbayo & Froehlich (2012)		sp 147	*Choeradoplana gladismariae*	Ribeirão Grande/SP	-24.26	-48.40
F6166	Pq Mun Nasc Paranapiacaba	sp 148	*Obama otavioi*	Santo André	-23.77942132451774	-46.29898242952317
F6192	Pq Mun Nasc Paranapiacaba	sp 148	*Obama otavioi*	Santo André	-23.77942132451774	-46.29898242952317
F6602	Vila de Paranapiacaba e caminho de acesso	sp 148	*Obama otavioi*	Santo André	-23.779001	-46.300616
Carbayo et al (2016)		sp 148	*Obama otavioi*	Santo André/SP	-23.77637	-46.31195
F2189	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F2191	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F2192	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F2193	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4004	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4006	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4014	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4017	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4041	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
F4074	PE Desengano	sp 149	*Cratera cuarassu*	Santa Maria Madalena	-21.87	-41.91
Carbayo & Almeida (2015)		sp 149	*Cratera cuarassu*	Santa Maria Madalena/RJ	-21.87	-41.91
Froehlich (1959)		sp 15	*Obama assu*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 15	*Obama assu*	Rio do Testo/SC	-26.743720	-49.175644
F1337	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.49659397554616	-43.00236847415091
F2557	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F2559	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F2594	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F2595	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F2605	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F2622	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.455277777777777	-42.9975
F4190	Parnaso	sp 150	*Cratera anamariae*	Teresópolis	-22.45638888888889	-42995
Carbayo & Almeida (2015)		sp 150	*Cratera anamariae*	Teresópolis/RJ	-22.500057	-42.997365
F2623	Parnaso	sp 151	*Paraba piriana*	Teresópolis	-22.455277777777777	-42.9975
Almeida et al (2012)		sp 151	*Paraba piriana*	Teresópolis/RJ	-22.45528	-42.99750
Almeida et al (2012)		sp 152	*Paraba tingauna*	Paulo Lopes/SC	-27.865111	-48.919389
Almeida et al (2012)		sp 152	*Paraba tingauna*	Paulo Lopes/SC	-27.94944	-48.79556
Carbayo et al (2013)		sp 153	*Cephaloflexa araucariana*	São Francisco de Paula/RS	-29.42736	-50.39838
Carbayo et al (2013)		sp 154	*Cratera picuia*	Matinhos/PR	-25.76437	-48.62266
Lago-Barcia et al., 2020 / F7325		sp 155	*Imbira guaiana*	PN São Joaquim	-28.039273	-49.614560

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Amaral et al (2014)		sp 155	*Imbira guaiana*	Salvador do Sul/RS	-29.442428	-51.502151
Leal-Zanchet & Carbayo (2001)		sp 155	*Imbira guaiana*	São Francisco de Paula/RS	-29.41666	-50.38333
Graff (1899)		sp 156	*Choeradoplana spatulata*	Blumenau/SC	-27.04836	-49.09200
Graff (1899)		sp 157	*Rhynchodemus blainvillei*	Blumenau/SC	-27.04836	-49.09200
Graff (1899)		sp 158	*Anisorhynchodemus pellucidus*	Blumenau/SC	-27.04836	-49.09200
Graff (1899)		sp 159	*Choeradoplana ehrenreichi*	Joinville/SC	-26.28	-48.86
Froehlich (1959)		sp 16	*Luteostriata fita*	Blumenau/SC	-27.05386	-49.08606
Graff (1899)		sp 160	*Obama argus*	Nova Friburgo/RJ	-22.26	-42.56
Carbayo et al (2018)		sp 161	*Choeradoplana iheringi*	Parobé/RS	-29.63	-50.87
Carbayo et al (2018)		sp 161	*Choeradoplana iheringi*	São Francisco de Paula/RS	-29.427361	-50.398389
Graff (1899)		sp 161	*Choeradoplana iheringi*	Taquara/RS	-29.659801	-50.779542
F2840	PN Bocaina	sp 162	*Choeradoplana pucupucu*	São José do Barreiro	-22.7501	-44.6208
F2844	PN Bocaina	sp 162	*Choeradoplana pucupucu*	São José do Barreiro	-22.7501	-44.6208
F2847	PN Bocaina	sp 162	*Choeradoplana pucupucu*	São José do Barreiro	-22.7501	-44.6208
Almeida et al (2018)		sp 162	*Choeradoplana pucupucu*	Ribeirão Pires/SP	-23.701329	-46.39
Almeida et al (2018)		sp 162	*Choeradoplana pucupucu*	São José do Barreiro/SP	-22.74	-44.61
Almeida et al (2018)		sp 162	*Choeradoplana pucupucu*	Teresópolis/RJ	-22.439089	-42.994351
Almeida et al (2018)		sp 163	*Choeradoplana abaiba*	Paulo Lopes/SC	-27.947500	-48.751111
Almeida et al (2018)		sp 163	*Choeradoplana abaiba*	Paulo Lopes/SC	-27.961389	-48.758333
Almeida et al (2018)		sp 163	*Choeradoplana abaiba*	São Bonifácio/SC	-27.84	-48.92
F2204	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F2205	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F2214	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F3952	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F3967	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F3999	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F4000	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
F4060	PE Desengano	sp 164	*Choeradoplana agua*	Santa Maria Madalena	-21.87	-41.91
Almeida et al (2018)		sp 164	*Choeradoplana agua*	Santa Maria Madalena/RJ	-21.876667	-41.919722
F4021	PE Desengano	sp 165	*Obama anthropophila*	Santa Maria Madalena	-21.87	-41.91
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Blumenau/SC	-27.05386	-49.08606
Lago-Barcia et al., 2020 / F3360		sp 165	*Obama anthropophila*	FLONA-SFP	-29.428944	-50.392000
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Ivoti/RS	-29.610000	-51.163611
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Novo Hamburgo/RS	-29.72	-51.12
Carbayo et al (2016)		sp 165	*Obama anthropophila*	Paulo Lopes/SC	-27.84278	-48.92583
Lago-Barcia et al., 2020 / F2647		sp 165	*Obama anthropophila*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3346		sp 165	*Obama anthropophila*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F1414		sp 165	*Obama anthropophila*	PN Itajaí	-27.04836	-49.09206
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Portão/RS	-29.69	-51.27
Carbayo et al (2016)		sp 165	*Obama anthropophila*	Ribeirão Grande/SP	-24.26	-48.40
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Salvador do Sul/RS	-29.440556	-51.507778
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	São Bonifácio/SC	-27.84	-48.92
Álvarez-Presas et		sp 165	*Obama anthropophila*	São Francisco de	-29.42964	-50.39783

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
al (2015)				Paula/RS		
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	São Paulo/SP	-23.50	-46.54
Álvarez-Presas et al (2015)		sp 165	*Obama anthropophila*	Taquara/RS	-29.659801	-50.779542
Álvarez-Presas et al. 2015, Carbayo et al (2016)	Santa Maria	sp 166	*Obama decidualis*	Santa Maria/RS	-29.74167	-53.84417
Álvarez-Presas et al. 2015, Carbayo et al (2016)	Santa Maria	sp 166	*Obama decidualis*	Santa Maria/RS	-29.74167	-53.84417
Álvarez-Presas et al. 2015, Carbayo et al (2016)	Santa Maria	sp 166	*Obama decidualis*	Santa Maria/RS	-29.74167	-53.84417
Álvarez-Presas et al. 2015, Carbayo et al (2016)	Santa Maria	sp 166	*Obama decidualis*	Santa Maria/RS	-29.74167	-53.84417
Carbayo et al (2016)		sp 167	*Obama nungara*	Paulo Lopes/SC	-27.959689875508015	-48.757664746
Carbayo et al (2016)		sp 167	*Obama nungara*	Paulo Lopes/SC	-27.959689875508015	-48.757664746
Carbayo et al (2016)		sp 167	*Obama nungara*	Paulo Lopes/SC	-27.959689875508015	-48.757664746
Carbayo et al (2016)		sp 167	*Obama nungara*	Paulo Lopes/SC	-27.959689875508015	-48.757664746
Lago-Barcia et al., 2020 / F7439		sp 167	*Obama nungara*	PN São Joaquim	-27.959777	-49.482612
Almeida et al (2018) (F2077)		sp 168	*Geoplana boraceia*	Salesópolis/SP	-23.75203	-45.631027
Almeida et al (2018) (F2070)		sp 168	*Geoplana boraceia*	São Sebastião/SP	-23.75203	-45.631027
Almeida et al (2018)		sp 169	*Geoplana chita*	Morretes/PR	-25.469604	-48.813739
Froehlich (1959)		sp 17	*Paraba gaucha*	Salvador do Sul/RS	-29.436817	-51.527611
Antunes et al (2008)		sp 17	*Paraba gaucha*	São Leopoldo/RS	-29.764171	-51.155840
Antunes et al (2008)		sp 17	*Paraba gaucha*	Viamão/RS	-30.345738	-51.027817
Almeida et al (2018) (F1611)		sp 170	*Geoplana cambara*	Matinhos/PR	-25.71	-48.62
Almeida et al (2018) (F1635)		sp 170	*Geoplana cambara*	Matinhos/PR	-25.76437	-48.62266
F4097	PE Ilha do Cardoso, ambiente de floresta	sp 171	*Geoplana cananeia*	Cananeia	-25.091235	-47.928957
F4096	PE Ilha do Cardoso, ambiente de restinga	sp 171	*Geoplana cananeia*	Cananeia	-25.091235	-47.928957
Almeida et al (2018)		sp 171	*Geoplana cananeia*	Cananeia/SP	-25.091235	-47.928957
F7004	em volta da hospedaria do Pq Estadual Serra do Mar, Caraguatatuba	sp 172	*Geoplana caraguatatuba*	Caraguatatuba	-23.593880	-45.429746
F6727	Pq Est Serra do Mar – Caraguatatuba	sp 172	*Geoplana caraguatatuba*	Caraguatatuba	-23.594012	-45.429672
Almeida et al (2018)		sp 172	*Geoplana caraguatatuba*	Caraguatatuba/SP	-23.594012	-45.429672
F6999	Pico do Jaraguá	sp 173	*Geoplana ibiuna*	São Paulo	-23.457976	-46.763849
Almeida et al (2018) (F3562)		sp 173	*Geoplana ibiuna*	Ibiúna/SP	-23.93	-47.19
Almeida et al (2018) (F6907)		sp 173	*Geoplana ibiuna*	Santana de Parnaiba/ SP	-23.449229	-47.012175
Lago-Barcia et al., 2020 / F3166		sp 174	*Geoplana iporanga*	PE Intervales	-24.269387	-48.405467
Almeida et al (2018)		sp 174	*Geoplana iporanga*	Ribeirão Grande/SP	-24.269387	-48.405467
F7000	Parque do Estado	sp 175	*Geoplana mogi*	São Paulo	-23.652247	-46.627088
F1022	Sítio Prof. Menna	sp 175	*Geoplana mogi*	Mogi das Cruzes	-23.451536	-46.227993
Almeida et al (2018)		sp 175	*Geoplana mogi*	Mogi das Cruzes/SP	-23.451536	-46.227993
Almeida et al (2018)		sp 175	*Geoplana mogi*	São Paulo/SP	-23.570942	-46.693776
F6998	Paranapiacaba	sp 176	*Geoplana paranapiacaba*	Santo André	-23.779001	-46.300616
Almeida et al (2018)		sp 176	*Geoplana paranapiacaba*	Santo André/SP	-23.77746	-46.30145

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F1163	Pq da Previdência	sp 177	*Geoplana piratininga*	São Paulo	-23.579662	-46.727503
F5134	Pq Previdência	sp 177	*Geoplana piratininga*	São Paulo	-23.579662	-46.727503
Almeida et al (2018)		sp 177	*Geoplana piratininga*	São Paulo/SP	-23.490918	-46.516424
F6387	PE Pedra Branca	sp 178	*Geoplana vaginuloides*	Rio de Janeiro	-22.93707	-43.92557
Darwin (1844)		sp 178	*Geoplana vaginuloides*	Rio de Janeiro/RJ	-22.93707	-43.46098
Riester (1938)		sp 178	*Geoplana vaginuloides*	Teresópolis/RJ	-22.439089	-42.994351
Almeida et al (2018) (F2072)		sp 179	*Geoplana apua*	Nova Iguaçu	-22.720167037968825	-43.490270757610645
Almeida et al (2018) (F2090)		sp 179	*Geoplana apua*	Nova Iguaçu/RJ	-22.71	-43.56
froehlich (1959)		sp 18	*Obama glieschi*	Iraí/RS	-27.242571	-53.272863
F2151	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F2158	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F3982	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F3984	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F4057	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F4083	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F4085	PE Desengano	sp 180	*Issoca assanga*	Santa Maria Madalena	-21.87	-41.91
F2250	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2266	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2274	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2277	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2278	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2279	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2290	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
F2296	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.904722222222222	-40.55027777777777
F2308	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2309	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2335	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2336	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2339	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2388	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2394	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19875	-40.53527777777778
F2429	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2445	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.91222222222222	-40.53611111111111
F2448	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.91222222222222	-40.53611111111111
F2459	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.91222222222222	-40.53611111111111
F2470	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.91222222222222	-40.53611111111111
F2489	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2492	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2493	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2498	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2507	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2512	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2535	RB Ruschi	sp 180	*Issoca assanga*	Santa Teresa	-19.88	-40.54
Almeida et al (2018)		sp 180	*Issoca assanga*	Santa Maria Madalena/RJ	-21.87694	-41.92583
Almeida et al (2018)		sp 180	*Issoca assanga*	Santa Teresa/ES	-19.88740	-40.54319
F4185	Parnaso	sp 181	*Barreirana bilineata* *	Teresópolis	-22.45638888888889	-42995
Lago-Barcia et al., 2020 / F2638		sp 182	*Geoplana sp. 9*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3804		sp 183	*Geoplaninae 7*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3764	Intervales	sp 184	*Supramontana * 10*	PE Intervales	-24.269387	-48.405467
F3103		sp 185	*Supramontana * 11*	PE Intervales	-24.269387	-48.405467
F3754e		sp 185	*Supramontana * 11*	PE Intervales	-24.269387	-48.405467
F3759		sp 185	*Supramontana * 11*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3758		sp 185	*Supramontana * 11*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3099		sp 186	*Obama sp. 8*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F1715		sp 186	*Obama sp. 8*	PN Saint Hilaire	-25.469604	-48.813739
F2636	Parnaso	sp 187	*Barreirana nao cassula* *	Teresópolis	-22.455277777777777	-42.9975
F2767		sp 188	*Obama sp. 24*	PE Intervales	-24.269387	-48.405467
F3788		sp 188	*Obama sp. 24*	PE Intervales	-24.269387	-48.405467
F3789		sp 188	*Obama sp. 24*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3754c		sp 188	*Obama sp. 24*	PE Intervales	-24.269387	-48.405467

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F2637		sp 189	*Paraba tata*	PE Intervales	-24.269387	-48.405467
F3151		sp 189	*Paraba tata*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3768		sp 189	*Paraba tata*	PE Intervales	-24.269387	-48.405467
F1770	PE Alberto Löfgren	sp 19	*Pasipha hauseri*	São Paulo	-23.462758168233385	-46.63700659481653
Amaral et al (2014)		sp 19	*Pasipha hauseri*	Salvador do Sul/RS	-29.436817	-51.527611
Froehlich (1959)		sp 19	*Pasipha hauseri*	São Leopoldo/RS	-29.764171	-51.155840
Lago-Barcia et al., 2020 / F2692		sp 190	*Geoplaninae X*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3754d		sp 191	*Paraba sp. 9*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F6511		sp 192	*Pasipha sp. 8*	Alfredo Wagner/SC	-27.61727	-49.35075
Lago-Barcia et al., 2020 / F3102		sp 192	*Pasipha sp. 8*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3239		sp 192	*Pasipha sp. 8*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F7416		sp 192	*Pasipha sp. 8*	PN São Joaquim	-28.161997	-49.627107
Lago-Barcia et al., 2020 / F3482		sp 193	*Pasipha sp. 11*	FLONA-SFP	-29.428944	-50.392000
F3176		sp 194	*Xerapoa sp. 1*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3115		sp 194	*Xerapoa sp. 1*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3090		sp 195	*Xerapoa sp. 2*	PE Intervales	-24.269387	-48.405467
F2020	PE Cantareira	sp 196	*Obama cantaritatiayanensis* *	São Paulo	-23.435798019670848	-46.63520404067118
F3007	PE Cantareira	sp 196	*Obama cantaritatiayanensis* *	São Paulo	-23.42	-46.63
Lago-Barcia et al., 2020 / F3417		sp 197	*Choeradoplana eudoxiae*	FLONA-SFP	-29.436278	-50.373694
F2225	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3922	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3931	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3936	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3953	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3961	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3994	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
F3996	PE Desengano	sp 198	*Barreirana sanguinolenta Desengano*	Santa Maria Madalena	-21.87	-41.91
Lago-Barcia et al., 2020 / F3388		sp 199	*Notogynaphallia sp. X*	FLONA-SFP	-29.427361	-50.398389
Negrete & Brusa (2017)		sp 2	*Pasipha quirogai*	San Ignacio	-27.27944	-55.57861
F2384	RB Ruschi	sp 20	*Pasipha tapetilla preta* *	Santa Teresa	-19875	-40.53527777777778
Froehlich, 1959	Chapada	sp 200	*"Geoplana" beckeri*	Salvador (BA)	-12.843490922204259	-38.44209094888567
Lago-Barcia et al., 2020 / F3395		sp 201	*Paraba sp. 2*	FLONA-SFP	-29.427361	-50.398389
F3468		sp 202	*Petitpua g. n. gaucha* *	FLONA-SFP	-29.42	-50.39
F2314	RB Ruschi	sp 203	*Cratera-laranjinegra_2* *	Santa Teresa	-19875	-40.53527777777778
F2513	RB Ruschi	sp 203	*Cratera-laranjinegra_2* *	Santa Teresa	-19.88722222222222	-40.543055555555554
Froehlich (1959)		sp 204	*Cephaloflexa nataliae*	Blumenau/SC	-27.05386	-49.08606
F2103	PN Bocaina	sp 205	*Cephaloflexa viridis sp.n*	São José do Barreiro	-22.7501	-44.6208
F2108	PN Bocaina	sp 205	*Cephaloflexa viridis sp.n*	São José do Barreiro	-22.7501	-44.6208
Lago-Barcia et al., 2020 / F3394		sp 206	*Cratera pavanioides* *	FLONA-SFP	-29.42	-50.39
Lemos et al., 2014		sp 207	*Choeradoplana minima*	São Francisco de Paula/RS	-29.42	-50.39
Lago-Barcia et al., 2020 / F0406		sp 208	*Matuxia tymbyra*	FLONA-SFP	-29.42	-50.39

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Lago-Barcia et al., 2020 / F3425		sp 209	*Paraba sp. 1*	FLONA-SFP	-29.42	-50.39
Froehlich (1959)		sp 21	*Paraba suva*	Blumenau/SC	-27.05386	-49.08606
F2689		sp 210	*Issoca intervales sp.n .*	PE Intervales	-24.269387	-48.405467
F2364	RB Ruschi	sp 211	*Choeradoplana clara no meio **	Santa Teresa	-19875	-40.53527777777778
F7270		sp 212	*Choeradoplana sp. 5*	PN São Joaquim	-28.162037	-49.627140
F7283		sp 212	*Choeradoplana sp. 5*	PN São Joaquim	-28.162037	-49.627140
F7659		sp 212	*Choeradoplana sp. 5*	PN São Joaquim	-28.162037	-49.627140
Lago-Barcia et al., 2020 / F7262		sp 212	*Choeradoplana sp. 5*	PN São Joaquim	-28.162037	-49.627140
F7291		sp 213	*Choeradoplana sp. 9*	PN São Joaquim	-28.038422	-49.613814
F7443		sp 213	*Choeradoplana sp. 9*	PN São Joaquim	-28.038422	-49.613814
F7675		sp 213	*Choeradoplana sp. 9*	PN São Joaquim	-28.038422	-49.613814
Lago-Barcia et al., 2020 / F7292		sp 213	*Choeradoplana sp. 9*	PN São Joaquim	-28.038422	-49.613814
F6543		sp 214	*Choeradoplana sp. 7*	Alfredo Wagner/SC	-27.61727	-49.35075
Lago-Barcia et al., 2020 / F6537		sp 214	*Choeradoplana sp. 7*	Alfredo Wagner/SC	-27.61727	-49.35075
Lago-Barcia et al., 2020 / F7419		sp 215	*Luteostriata sp. 3*	PN São Joaquim	-28.161771	-49.627752
F2255	RB Ruschi	sp 216	*Choeradoplana claudioi*	Santa Teresa	-19.88	-40.54
F2424	RB Ruschi	sp 216	*Choeradoplana claudioi*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2497	RB Ruschi	sp 216	*Choeradoplana claudioi*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2499	RB Ruschi	sp 216	*Choeradoplana claudioi*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2510	RB Ruschi	sp 216	*Choeradoplana claudioi*	Santa Teresa	-19.88722222222222	-40.543055555555554
Lago-Barcia et al., 2020 / F7241		sp 217	*Obama sp. 9*	PN São Joaquim	-28.140017	-49.629717
Lago-Barcia et al., 2020 / F7240		sp 218	*Obama sp. 10*	PN São Joaquim	-28.140421	-49.627143
Lago-Barcia et al., 2020 / F7318		sp 219	*Obama sp. 11*	PN São Joaquim	-28.038786	-49.614039
Lago-Barcia et al., 2020 / F1634		sp 22	*Luteostriata sp 4*	Saint-Hilaire	-25.71	-48.62
F7404		sp 220	*Obama sp. 13*	PN São Joaquim	-28.235706	-49.498816
F7758		sp 220	*Obama sp. 13*	PN São Joaquim	-28.235706	-49.498816
F7764		sp 220	*Obama sp. 13*	PN São Joaquim	-28.235706	-49.498816
F7766		sp 220	*Obama sp. 13*	PN São Joaquim	-28.235706	-49.498816
Lago-Barcia et al., 2020 / F7389		sp 220	*Obama sp. 13*	PN São Joaquim	-28.235706	-49.498816
Lago-Barcia et al., 2020 / F7378		sp 221	*Obama apiguara*	PN São Joaquim	-28.235617	-49.498897
Iturralde & Leal-Zanchet, 2019		sp 222	*Choeradoplana cyanoatria*	Três Barras	-26.221555207469297	-50.31421831692109
Iturralde & Leal-Zanchet, 2019		sp 223	*Choeradoplana longivesicula*	General Carneiro	-26.398203	-51.404433
F7354		sp 224	*Obama sp. 22*	PN São Joaquim	-28.038432	-49.613820
F7464		sp 224	*Obama sp. 22*	PN São Joaquim	-28.038432	-49.613820
F7466		sp 224	*Obama sp. 22*	PN São Joaquim	-28.038432	-49.613820
Lago-Barcia et al., 2020 / F7352		sp 224	*Obama sp. 22*	PN São Joaquim	-28.038432	-49.613820
Lago-Barcia et al., 2020 / F7362		sp 225	*Obama sp. 21*	PN São Joaquim	-28.038432	-49.613820
Lago-Barcia et al., 2020 / F7363		sp 225	*Obama sp. 21*	PN São Joaquim	-28.038432	-49.613820
Lago-Barcia et al., 2020 / F3859		sp 226	*Geoplaninae XX*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F7385		sp 226	*Geoplaninae XX*	PN São Joaquim	-28.235617	-49.498897
F4022	PE Desengano	sp 227	*Choeradoplana não agua **	Santa Maria Madalena	-21.87	-41.91
F4063	PE Desengano	sp 227	*Choeradoplana não agua **	Santa Maria Madalena	-21.87	-41.91
F4089	PE Desengano	sp 227	*Choeradoplana não agua **	Santa Maria Madalena	-21.87	-41.91
Lago-Barcia et al., 2020 / F7272		sp 228	*Geoplaninae XY*	PN São Joaquim	-28.275805	-49.549801
Lago-Barcia et al., 2020 / F7315		sp 229	*Geoplaninae A*	PN São Joaquim	-28.038422	-49.613814
Schultze & Müller (1857)		sp 23	*Notogynaphallia atra*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 23	*Notogynaphallia atra*	Brusque/SC	-27.111325	-48.895427
Froehlich (1959)		sp 23	*Notogynaphallia atra*	Itajaí/SC	-26.957485	-48.756133
Froehlich (1959)		sp 23	*Notogynaphallia atra*	Lapa/PR	-25.834333	-49.904062
Froehlich (1959)		sp 23	*Notogynaphallia atra*	Rio do Testo/SC	-26.743720	-49.175644
Graff (1899)		sp 23	*Notogynaphallia atra*	Taquara/RS	-29.659801	-50.779542
Lago-Barcia et al.,		sp 230	*Pasipha sp. 3*	PN São Joaquim	-28.161958	-49.627265

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
2020 / F7418						
F3796		sp 231	*Pasipha sp. X*	PE Intervales	-24.269387	-48.405467
F2230	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.88	-40.54
F2235	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.88	-40.54
F2281	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.88	-40.54
F2286	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.88	-40.54
F2310	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19875	-40.53527777777778
F2311	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19875	-40.53527777777778
F2414	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.88967423012325	-40.5523895144634
F2414	RB Ruschi	sp 232	*Choeradoplana onae*	Santa Teresa	-19.878611111111113	-40.53944444444444
Lago-Barcia et al., 2020 / F7476		sp 233	*Pasipha sp. 12*	PN São Joaquim	-27.960810	-49.483000
Lago-Barcia et al., 2020 / F7248		sp 234	*Geoplaninae 9*	PN São Joaquim	-28.14187	-49.63534
Lago-Barcia et al., 2020 / F2689		sp 235	*Issoca intervales sp.n .*	PE Intervales	-24.269387	-48.405467
F2256	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88	-40.54
F2265	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88	-40.54
F2280	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88	-40.54
F2397	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2403	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2410	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2416	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2483	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2484	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2494	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2496	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2501	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2508	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2511	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2514	RB Ruschi	sp 236	*Choeradoplana pseudobocaina* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F7363		sp 237	*Geoplaninae 12*	PN São Joaquim	-28.038610	-49.613914
Lago-Barcia et al., 2020 / F7338		sp 238	*Geoplaninae 13*	PN São Joaquim	-28.039749	-49.614906
Lago-Barcia et al., 2020 / F7322		sp 239	*Xerapoa sp. 3*	PN São Joaquim	-28.039273	-49.614560
Graff (1899)		sp 24	*"Geoplana" nigra*	Taquara/RS	-29.659801	-50.779542
Lago-Barcia et al., 2020 / F7316		sp 240	*Xerapoa sp. 5*	PN São Joaquim	-28.040082	-49.615061
Lago-Barcia et al., 2020 / F3352		sp 241	*Geoplaninae 1* *	PE Tabuleiro	-27.86	-48.91
Lago-Barcia et al., 2020 / F3228		sp 242	*Geoplaninae B*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F3238		sp 243	*Obama sp. 2*	PE Tabuleiro	-27.84	-48.92
F2353	RB Ruschi	sp 244	*Choeradoplana pseudogladismariae* *	Santa Teresa	-19875	-40.53527777777778
Lago-Barcia et al., 2020 / F6537	Trilha dentro da RPPN Vale das Pedras que antecede o rio	sp 244	*Choeradoplana pseudogladismariae* *	Alfredo Wagner	-27.61735	-49.34919
Lago-Barcia et al., 2020 / F3186		sp 245	*Choeradoplana sp. 4*	PE Tabuleiro	-27.94	-48.79
Lago-Barcia et al., 2020 / F3226	Tabuleiro	sp 246	*Choeradoplana tristriata*	Paulo Lopes	-27.94	-48.79
Schultze & Müller, 1857		sp 246	*Choeradoplana tristriata*	Blumenau	-27.04836	-49.09200
F5507	PE C Jordao	sp 247	*Choeradoplana riscospretos* *	Campos do Jordão	-22.68829	-45.48042
F3929	PE Desengano	sp 248	*Xerapoa desengano* *	Santa Maria Madalena	-21.87	-41.91
F3969	PE Desengano	sp 248	*Xerapoa desengano* *	Santa Maria Madalena	-21.87	-41.91
F3970	PE Desengano	sp 248	*Xerapoa desengano* *	Santa Maria Madalena	-21.87	-41.91
F4217	Parnaso	sp 249	*Choeradoplana riutortae*	Teresópolis	-22.45638888888889	-42995

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F4218	Parnaso	sp 249	*Choeradoplana riutortae*	Teresópolis	-22.45638888888889	-42995
F4261	Parnaso	sp 249	*Choeradoplana riutortae*	Teresópolis	-22.45138888888889	-43.00138888888889
F4291	Parnaso	sp 249	*Choeradoplana riutortae*	Teresópolis	-22.45138888888889	-43.00138888888889
Álvarez-Presas et al (2014)		sp 25	*Cephaloflexa bergi*	São Paulo/SP	-23.4300	-46.6333
Lago-Barcia et al., 2020 / F3241		sp 250	*Geoplaninae 8*	PE Tabuleiro	-27.94	-48.79
F3796		sp 251	*Pasipha sp. X*	PE Intervales	-24.269387	-48.405467
F3283		sp 252	*Supramontana * 2 estrias*	PE Tabuleiro	-27.840735	-48.924866
F3310		sp 252	*Supramontana * 2 estrias*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F3289		sp 252	*Supramontana * 2 estrias*	PE Tabuleiro	-27.840735	-48.924866
F2294	RB Ruschi	sp 253	*Choeradoplana sexstriata **	Santa Teresa	-19.904722222222222	-40.55027777777777
Lago-Barcia et al., 2020 / F3888		sp 254	*Notogynaphallia sp. 4*	PE Tabuleiro	-27.840735	-48.924866
F2332	RB Ruschi	sp 255	*Choeradoplana sp in Lagoetal2021Zookeys pseudobocaina-Ruschi * 1*	Santa Teresa	-19875	-40.53527777777778
F2390	RB Ruschi	sp 255	*Choeradoplana sp in Lagoetal2021Zookeys pseudobocaina-Ruschi * 2*	Santa Teresa	-19875	-40.53527777777778
F4252	Parnaso	sp 256	*Cratera anamariae*	Teresópolis	-22.45138888888889	-43.00138888888889
F2025	PN Bocaina	sp 257	*Cratera assu*	São José do Barreiro	-22.7501	-44.6208
F2807	PN Bocaina	sp 257	*Cratera assu*	São José do Barreiro	-22.7501	-44.6208
F2821	PN Bocaina	sp 257	*Cratera assu*	São José do Barreiro	-22.7501	-44.6208
F2825	PN Bocaina	sp 257	*Cratera assu*	São José do Barreiro	-22.7501	-44.6208
F2834	PN Bocaina	sp 257	*Cratera assu*	São José do Barreiro	-22.7501	-44.6208
F2828	PN Bocaina	sp 258	*Cratera boja*	São José do Barreiro	-22.7501	-44.6208
F2829	PN Bocaina	sp 258	*Cratera boja*	São José do Barreiro	-22.7501	-44.6208
F2349	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19875	-40.53527777777778
F2439	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.878611111111113	-40.53944444444444
F2446	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2447	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2455	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2469	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2487	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.88722222222222	-40.543055555555554
F2528	RB Ruschi	sp 259	*Cratera caramelo leve **	Santa Teresa	-19.88722222222222	-40.543055555555554
F5878	EcoPark Aruã	sp 26	*Obama burmeisteri*	Mogi das Cruzes	-23.46273	-46.26598
F5914	EcoPark Aruã	sp 26	*Obama burmeisteri*	Mogi das Cruzes	-23.46426	-46.26573
F7003	em volta da hospedaria do Pq Estadual Serra do Mar, Caraguatatuba	sp 26	*Obama burmeisteri*	Caraguatatuba	-23.593880	-45.429746
F0605	Fazenda São Camilo, Suarão	sp 26	*Obama burmeisteri*	Itanhaém	-24.142746236136063	-46.760945309404384
F6376	Paranapiacaba	sp 26	*Obama burmeisteri*	Santo André	-23.779001	-46.300616
F6394A	Paranapiacaba	sp 26	*Obama burmeisteri*	Santo André	-23.779001	-46.300616
F0541	Parelheiros	sp 26	*Obama burmeisteri*	São Paulo	-23.86922197151502	-46.70686865270446
F0542	Parelheiros	sp 26	*Obama burmeisteri*	São Paulo	-23.86922197151502	-46.70686865270446
F1122	Parnaso	sp 26	*Obama burmeisteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1123	Parnaso	sp 26	*Obama burmeisteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1125	Parnaso	sp 26	*Obama burmeisteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1126	Parnaso	sp 26	*Obama burmeisteri*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1755	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1775	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1778	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1779	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F1784	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1786	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1788	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1811	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1827	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1862	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1888	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1915	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1935	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3619	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3620	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3621	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3622	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3623	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3628	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3629	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3630	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3632	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3635	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3636	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3637	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3641	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3644	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3645	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3646	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3647	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3649	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3651	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3652	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3655	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3656	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3657	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3658	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3663	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3673	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F3676	PE Alberto Löfgren	sp 26	*Obama burmeisteri*	São Paulo	-23.462758168233385	-46.63700659481653
F1937	PE Cantareira	sp 26	*Obama burmeisteri*	São Paulo	-23.435798019670848	-46.63520404067118
F2886	PE Cantareira	sp 26	*Obama burmeisteri*	São Paulo	-23.460277777777776	-46.63666666666666
F2899	PE Cantareira	sp 26	*Obama burmeisteri*	São Paulo	-23.460277777777776	-46.63666666666666
F2909	PE Cantareira	sp 26	*Obama burmeisteri*	São Paulo	-23.460277777777776	-46.63666666666666
F2930	PE Cantareira	sp 26	*Obama burmeisteri*	São Paulo	-23.460277777777776	-46.63666666666666
F6388	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93707	-43.92557
F6392	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93707	-43.92557
F6409	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-25.09544	-47.92557

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F6419	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93402	-43.44584
F6430	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93409	-43.45163
F6435	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93409	-43.45163
F6440	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95708	-43.44801
F6445	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95681	-43.44840
F6450	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95681	-43.44840
F6476	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93398	-43.44793
F6497	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93835	-43.46233
F6500	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93738	-43.46145
F6746	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93656	-043.45794
F6755	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93363	-043.44794
F6792	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93698	-043.46106
F6803	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93698	-043.45967
F6825	PE Pedra Branca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.93788	-043.46199
F5298	PESM-Itutinga-Piloes	sp 26	*Obama burmeisteri*	Cubatão	-23.90509	-46.48940
F1057	Pico do Jaraguá	sp 26	*Obama burmeisteri*	São Paulo	-23.457941033706927	-46.766864661974545
F5153	PN Itatiaia	sp 26	*Obama burmeisteri*	Resende	-22.454444444444444	-44.60777777777778
F6217	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95584	-43.27995
F6227	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95586	-43.27997
F6232	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95588	-43.27999
F6233	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95589	-43.28000
F6244	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95625	-43.27784
F6248	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95684	-43.27742
F6251	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95689	-43.27742
F6253	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6254	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6259	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95689	-43.27742
F6294	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6297	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6302	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6316	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6322	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6324	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6338	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F7888	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F7889	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F7891	PN Tijuca	sp 26	*Obama burmeisteri*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F1211	Pq da Previdência	sp 26	*Obama burmeisteri*	São Paulo	-23.579662	-46.727503
F6673	Pq Est Serra do Mar – Caraguatatuba	sp 26	*Obama burmeisteri*	Caraguatatuba	-23.72972	-45.53284
F6206	Praia do Bonete	sp 26	*Obama burmeisteri*	Ilhabela	-23.917047649836622	-45.3446462937102
F2297	RB Ruschi	sp 26	*Obama burmeisteri*	Santa Teresa	-19875	-40.53527777777778
F0458	Reserva ambiental Hering Têxtil S/ A	sp 26	*Obama burmeisteri*	Blumenau	-26.911207756993	-49.086718444235096
F0461	Reserva ambiental Hering Têxtil S/ A	sp 26	*Obama burmeisteri*	Blumenau	-26.911207756993	-49.086718444235096
F5817	RPPN Ibirapitanga	sp 26	*Obama burmeisteri*	Santa Isabel	-23.28359	-46.29545
F1043	Sertão do Cambury (região da casa Menna)	sp 26	*Obama burmeisteri*	São Sebastião	-23.75203	-45.63103
F4331	Sertão do Cambury (região da casa Menna)	sp 26	*Obama burmeisteri*	São Sebastião	-23.75203	-45.63103
F4351	Sertão do Cambury (região da casa Menna)	sp 26	*Obama burmeisteri*	São Sebastião	-23.75203	-45.63103
F1033	Sítio Prof.	sp 26	*Obama burmeisteri*	Mogi das Cruzes	-23.451536	-46.227993

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
	Menna					
F6364	Vila de Paranapiacaba	sp 26	*Obama burmeisteri*	Santo André	-23.779001	-46.300616
F6373	Vila de Paranapiacaba	sp 26	*Obama burmeisteri*	Santo André	-23.779001	-46.300616
Froehlich (1956b)		sp 26	*Obama burmeisteri*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1956b)		sp 26	*Obama burmeisteri*	Brusque/SC	-27.111325	-48.895427
Froehlich (1956b)		sp 26	*Obama burmeisteri*	Itajaí/SC	-26.957485	-48.756133
Carbayo et al (2016)		sp 26	*Obama burmeisteri*	Jundiaí/SP	-23.21	-46.95
Froehlich (1956b)		sp 26	*Obama burmeisteri*	Matinhos/PR	-25.817820	-48.549932
Graff (1899)		sp 26	*Obama burmeisteri*	Morro Reuter/RS	-29.53	-51.07
CG Froehlich (1956a)		sp 26	*Obama burmeisteri*	Rio de Janeiro/RJ	-22.975852	-43.292230
Marcus (1951)		sp 26	*Obama burmeisteri*	São Paulo/SP	-23.500212	-46.702310
Carbayo et al (2016)		sp 26	*Obama burmeisteri*	Teresópolis/RJ	-22.439089	-42.994351
Froehlich (1956a)		sp 26	*Obama burmeisteri*	Ubatuba/SP	-23.423381	-45.083399
Lago-Barcia et al., 2020 / F4628		sp 260	*Geoplaninae C*	PN Itajai	-27.05386	-49.08606
Lago-Barcia et al., 2020 / F1415		Sp 261	*Geoplaninae 4*	PN Itajaí	-27.05306	-49.08528
Lago-Barcia et al., 2020 / F4627		Sp 262	*Geoplaninae 14*	PNItajai	-27.05386	-49.08606
F2234	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2248	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2260	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2264	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2273	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2283	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88	-40.54
F2320	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2326	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2350	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2351	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2383	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2386	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2393	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19875	-40.53527777777778
F2399	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2404	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2407	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2458	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2462	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2466	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2491	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2500	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2524	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2531	RB Ruschi	sp 263	*Cratera caramelo* *	Santa Teresa	-19.88722222222222	-40.543055555555554
Lago-Barcia et al., 2020 / F1707		Sp 264	*Geoplana sp. 3*	Saint-Hilaire	-25.469604	-48.813739
Lago-Barcia et al., 2020 / F3586		Sp 265	*Geoplaninae suja* *	Saint-Hilaire	-25.469604	-48.813739
Lago-Barcia et al., 2020 / F1638		sp 266	*Obama sp. 12*	Saint-Hilaire	-25.71	-48.62
F3930	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3945	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3948	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3959	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3971	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3974	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3976	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3985	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4018	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4036	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4048	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4051	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4056	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4062	PE Desengano	sp 267	*Cratera cremea Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4071	PE Desengano	sp 267	*Cratera cremea*	Santa Maria	-21.87	-41.91

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			Desengano *	Madalena		
F2927	PE Cantareira	sp 268	*Imbira atriangygina*	São Paulo	-23.460277777777776	-46.63666666666666
F3707	PE Cantareira	sp 268	*Imbira atriangygina*	São Paulo	-23.451890	-46.637104
F2482	RB Ruschi	sp 269	*Cratera ferussaci ruschi* *	Santa Teresa	-19.88722222222222	-40.543055555555554
Marcus (1951)		sp 27	*Paraba multicolor*	Avaré/SP	-23.096206	-48.914060
Leal-Zanchet & Matos (2011)		sp 27	*Paraba multicolor*	Caxias do Sul/RS	-29.194212	-51.165792
Froehlich (1956b)		sp 27	*Paraba multicolor*	Curitiba/PR	-25.548339	-49.313845
Froehlich (1957)		sp 27	*Paraba multicolor*	Guapiara/SP	-24.173828	-48.542533
Leal-Zanchet & Matos (2011)		sp 27	*Paraba multicolor*	Ibarama/RS	-29.722778	-53.714177
Froehlich (1956b)		sp 27	*Paraba multicolor*	Lapa/PR	-25.834333	-49.904062
Marcus (1951)		sp 27	*Paraba multicolor*	Mogi das Cruzes/SP	-23.505856	-46.211903
Lago-Barcia et al., 2020 / F2646		sp 27	*Paraba multicolor*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3301		sp 27	*Paraba multicolor*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F7317		sp 27	*Paraba multicolor*	PN São Joaquim	-28.040421	-49.615316
Froehlich (1957)		sp 27	*Paraba multicolor*	Ponta Grossa/PR	-25.101490	-50.174131
Leal-Zanchet & Matos (2011)		sp 27	*Paraba multicolor*	Santa Maria/RS	-29.722778	-53.714177
Marcus (1951)		sp 27	*Paraba multicolor*	Santo André/SP	-23.773397	-46.333248
Carbayo et al (2013)		sp 27	*Paraba multicolor*	São José do Barreiro/SP	-22.72583	-44.62611
Marcus (1951)		sp 27	*Paraba multicolor*	São Paulo/SP	-23.453148	-46.634488
CG Froehlich (1956a)		sp 27	*Paraba multicolor*	Teresópolis/RJ	-22.439089	-42.994351
F5512	PE C Jordao	sp 270	*Cratera imbiri*	Campos do Jordão	-22.68829	-45.48042
Boll et al 2019	State Park of Turvo	sp 271	*Cratera obsidiana*	Derrubadas	-27.19261832841472	-53.928800544964574
F5745	EB Boraceia	sp 272	*Cratera paraitinga*	Salesópolis	-23.65413	-45.89514
F5769	EB Boraceia	sp 272	*Cratera paraitinga*	Salesópolis	-23.65413	-45.89514
Lago-Barcia et al., 2020 / F7307		sp 273	*Geoplaninae nao-flamenco*	PN São Joaquim	-28.038422	-49.613814
F5765	EB Boraceia	sp 274	*Cratera pseudotamoia* *	Salesópolis	-23.65389	-45.88917
F5772	EB Boraceia	sp 274	*Cratera pseudotamoia* *	Salesópolis	-23.65389	-45.88917
F5785	EB Boraceia	sp 274	*Cratera pseudotamoia* *	Salesópolis	-23.65389	-45.88917
F5754	EB Boraceia	sp 275	*Cratera pseudotaxiarcha* *	Salesópolis	-23.65389	-45.88917
F5801	EB Boraceia	sp 275	*Cratera pseudotaxiarcha* *	Salesópolis	-23.65389	-45.88917
F3934	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3943	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3951	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3960	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3972	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F3973	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F4032	PE Desengano	sp 276	*Cratera republicana Desengano* *	Santa Maria Madalena	-21.87	-41.91
F2185	PE Desengano	sp 277	*Cratera tamoiosa* *	Santa Maria Madalena	-21.87	-41.91
F2031	PN Bocaina	sp 278	*Cratera tui*	São José do Barreiro	-22.7501	-44.6208
F2040	PN Bocaina	sp 278	*Cratera tui*	São José do Barreiro	-22.7501	-44.6208
F2054	PN Bocaina	sp 278	*Cratera tui*	São José do Barreiro	-22.7501	-44.6208
F2798	PN Bocaina	sp 278	*Cratera tui*	São José do Barreiro	-22.7501	-44.6208
F2809	PN Bocaina	sp 278	*Cratera tui*	São José do Barreiro	-22.7501	-44.6208
F5178	PN Itatiaia	sp 278	*Cratera tui*	Resende	-22.454444444444444	-44.60777777777778
F5190	PN Itatiaia	sp 278	*Cratera tui*	Resende	-22.454444444444444	-44.60777777777778
F2268	RB Ruschi	sp 279	*Cratera-laranjinegra_1* *	Santa Teresa	-19.88	-40.54
Graff (1899)		sp 28	*Obama polyophthalma*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1956b)		sp 28	*Obama polyophthalma*	Caiobá/PR	-25.817820	-48.549932
Graff (1899)		sp 28	*Obama polyophthalma*	Joinville/SC	-26.28	-48.86
Froehlich (1956b)		sp 28	*Obama polyophthalma*	Rio do Testo/SC	-26.743720	-49.175644
Lago-Barcia et al., 2020 / F1619		sp 28	*Obama polyophthalma*	Saint-Hilaire	-25.71	-48.62
Graff (1899)		sp 28	*Obama polyophthalma*	Taquara/RS	-29.659801	-50.779542
Leal-Zanchet & Marques, 2018		sp 280	*Difroehlichia elenae*	Conceição do Mato Dentro	-18.946694	-43.407667
F1070	EB Boraceia	sp 281	*Xerapoa boraceia*	Salesópolis	-23.65389	-45.88917
F2114	PN Bocaina	sp 282	*Xerapoa bocaina*	São José do Barreiro	-22.7501	-44.6208

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Negrete et al 2019		sp 283	*Winsoria bipatria*	Santa Maria, RS	-29.752281343870177	-53.88077160850521
Negrete et al 2019		sp 283	*Winsoria bipatria*	Santiago, RS	-29.18380419972299	-54.90383607598223
Schirch, 1929		sp 284	*Pseudogeoplana lumbricoides*	Teresópolis	-22.431959888773907	-43.005162984271685
F2027	PN Bocaina	sp 285	*Piima ata*	São José do Barreiro	-22.7501	-44.6208
F2796	PN Bocaina	sp 285	*Piima ata*	São José do Barreiro	-22.7501	-44.6208
F2400	RB Ruschi	sp 286	*genero novo? amarela gigante **	Santa Teresa	-19.878611111111113	-40.53944444444444
F2293	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.904722222222222	-40.55027777777777
F2450	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2467	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2476	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2478	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.91222222222222	-40.53611111111111
F2495	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.88722222222222	-40.543055555555554
F2532	RB Ruschi	sp 287	*Geobia ? com olhos **	Santa Teresa	-19.88722222222222	-40.543055555555554
F4112	EB Boraceia	sp 288	*Geoplana boraceia*	Salesópolis	-23.65389	-45.88917
F4389	Sertão do Cambury (região da casa Menna)	sp 288	*Geoplana boraceia*	São Sebastião	-23.75203	-45.63103
F4409	Sertão do Cambury (região da casa Menna)	sp 288	*Geoplana boraceia*	São Sebastião	-23.75203	-45.63103
F6026	Sertão do Cambury (região da casa Menna)	sp 288	*Geoplana boraceia*	São Sebastião	-23.74439	-45.63715
F6357	Sertão do Cambury (região da casa Menna)	sp 288	*Geoplana boraceia*	São Sebastião	-23.75203	-45.63103
F2934	PE Cantareira	sp 289	*Geoplana cantareirana sp.n.*	São Paulo	-23.42	-46.63
F2943	PE Cantareira	sp 289	*Geoplana cantareirana sp.n.*	São Paulo	-23.42	-46.63
F2944	PE Cantareira	sp 289	*Geoplana cantareirana sp.n.*	São Paulo	-23.42	-46.63
Riester (1938)		sp 29	*Obama carinata*	Ribeirão Pires/SP	-23.701329	-46.39
F5145	PN Itatiaia	sp 290	*Geoplana muitobonita **	Resende	-22.454444444444444	-44.60777777777778
F2521	RB Ruschi	sp 291	*Geoplaninae 1 * Geobia cinza*	Santa Teresa	-19.88722222222222	-40.543055555555554
F2387	RB Ruschi	sp 292	*Geoplaninae 2 **	Santa Teresa	-19875	-40.53527777777778
F2312	RB Ruschi	sp 293	*Geoplaninae 3 kawogrena **	Santa Teresa	-19875	-40.53527777777778
F2485	RB Ruschi	sp 293	*Geoplaninae 3 kawogrena **	Santa Teresa	-19.88722222222222	-40.543055555555554
F1308	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.47219469581555	-43.055074298022454
F2553	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.455277777777777	-42.9975
F2561	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.455277777777777	-42.9975
F2627	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.455277777777777	-42.9975
F4249	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.45138888888889	-43.00138888888889
F4250	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.45138888888889	-43.00138888888889
F4251	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.45138888888889	-43.00138888888889
F4317	Parnaso	sp 294	*Geoplaninae amarela **	Teresópolis	-22.45642	-42.99514
F6161	Pq Mun Nasc Paranapiacaba	sp 295	*Geoplaninae bela sp. n*	Santo André	-23.77942132451774	-46.29898242952317
F5764	EB Boraceia	sp 296	*Geoplaninae gen. n.? boraceia **	Salesópolis	-23.65389	-45.88917
F6179	Pq Mun Nasc Paranapiacaba	sp 297	*Geoplaninae olho-gato sp. .n.*	Santo André	-23.77942132451774	-46.29898242952317
F2379	RB Ruschi	sp 298	*Geoplaninae---negra-gris_**	Santa Teresa	-19875	-40.53527777777778
F2816	PN Bocaina	sp 299	*Geoplaninae-Piima xenon **	São José do Barreiro	-22.7501	-44.6208
Negrete & Brusa (2017)		sp 3	*Imbira negrita*	Moconá Provincial Park, Misiones province, Argentina	-27.14889	-53.898333
Negrete & Brusa (2017)		sp 3	*Imbira negrita*	Moconá Provincial Park, Misiones province, Argentina	-27.14889	-53.898333
Negrete & Brusa (2017)		sp 3	*Imbira negrita*	Moconá Provincial Park, Misiones province, Argentina	-27.14889	-53.898333

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
EMF 1955	PE Cantareira	sp 30	*Pasipha rosea*	São Paulo	-23.44416307180465	-46.63846833766449
F3021	PE Cantareira	sp 30	*Pasipha rosea*	São Paulo	-23.42	-46.63
F2049	PN Bocaina	sp 30	*Pasipha rosea*	São José do Barreiro	-22.7501	-44.6208
F2106	PN Bocaina	sp 30	*Pasipha rosea*	São José do Barreiro	-22.7501	-44.6208
F1061	Pq Estoril	sp 30	*Pasipha rosea*	São Bernardo do Campo	-23.77041542785824	-46.51941876161811
Froehlich (1956b)		sp 30	*Pasipha rosea*	Lapa/PR	-25.834333	-49.904062
EMF 1955		sp 30	*Pasipha rosea*	Pirassununga	-22.00377495649689	-47.434988437672025
EM Froehlich (1955a)		sp 30	*Pasipha rosea*	Pirassununga/SP	-22.007522	-47.459448
Carbayo et al (2013)		sp 30	*Pasipha rosea*	São Bernardo/SP	-23.77368	-46.51469
Lago-Barcia et al., 2020 / F2032		sp 30	*Pasipha rosea*	São José do Barreiro/SP	-22.78222	-44.60583
EM Froehlich (1955a)		sp 30	*Pasipha rosea*	São Paulo/SP	-23.453148	-46.634488
Froehlich (1957)		sp 30	*Pasipha rosea*	São Simão	-21.471847	-47.573321
FroehlichCG_1957 _On a collection of Brazilian Land Planarians		sp 30	*Pasipha rosea*	São Simão	-21.476779136289668	-47.56516164453126
F3065	PE Cantareira	sp 300	*Georetractor gen. n. penioides* *	São Paulo	-23.42	-46.63
F2190	PE Desengano	sp 301	*Geosanguinea gen. n. desengano* *	Santa Maria Madalena	-21.87	-41.91
F2206	PE Desengano	sp 301	*Geosanguinea gen. n. desengano* *	Santa Maria Madalena	-21.87	-41.91
F2207	PE Desengano	sp 301	*Geosanguinea gen. n. desengano* *	Santa Maria Madalena	-21.87	-41.91
F1326	Parnaso	sp 302	*Imbuhy gen. n. semicafusa* *	Teresópolis	-22.49659397554616	-43.00236847415091
Lago-Barcia et al., 2020 / F3796		sp 303	*Pasipha sp. X*	PE Intervales	-24.269387	-48.405467
F2102	PN Bocaina	sp 304	*Issoca jandaia bocaina 3 estrias* *	São José do Barreiro	-22.7501	-44.6208
F2042	PN Bocaina	sp 305	*Issoca jandaia bocaina 5 estrias* *	São José do Barreiro	-22.7501	-44.6208
F2043	PN Bocaina	sp 305	*Issoca jandaia bocaina 5 estrias* *	São José do Barreiro	-22.7501	-44.6208
F2799	PN Bocaina	sp 305	*Issoca jandaia bocaina 5 estrias* *	São José do Barreiro	-22.7501	-44.6208
F2815	PN Bocaina	sp 305	*Issoca jandaia bocaina 5 estrias* *	São José do Barreiro	-22.7501	-44.6208
F2938	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F2941	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F2942	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F3029	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F3047	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F3079	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F3515	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F3525	PE Cantareira	sp 306	*Issoca potyroides* *	São Paulo	-23.42	-46.63
F2170	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2176	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2194	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2195	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2196	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2197	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2198	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F2199	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3921	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3956	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3964	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3965	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3990	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F3997	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F4008	PE Desengano	sp 307	*Luteostriata basta sp. n*	Santa Maria Madalena	-21.87	-41.91
F4052	PE Desengano	sp 307	*Luteostriata basta sp.*	Santa Maria	-21.87	-41.91

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			n	Madalena		
F1063	EB Boraceia	sp 308	*Luteostriata caissara ubatuba* *	Salesópolis	-23.65389	-45.88917
F1064	EB Boraceia	sp 308	*Luteostriata caissara ubatuba* *	Salesópolis	-23.65389	-45.88917
F1078	EB Boraceia	sp 308	*Luteostriata caissara ubatuba* *	Salesópolis	-23.65389	-45.88917
F4151	EB Boraceia	sp 308	*Luteostriata caissara ubatuba* *	Salesópolis	-23.65389	-45.88917
F4170	EB Boraceia	sp 308	*Luteostriata caissara ubatuba* *	Salesópolis	-23.65389	-45.88917
EMF 1955		sp 308	*Luteostriata caissara ubatuba* *	Ubatuba	-23.430165662506674	-45.07343978307938
CG Froehlich (1956a)		sp 308	*Luteostriata caissara ubatuba* *	Ubatuba/SP	-23.423381	-45.083399
F1761	PE Alberto Löfgren	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.462758168233385	-46.63700659481653
F3695	PE Alberto Löfgren	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.462758168233385	-46.63700659481653
F2018	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.435798019670848	-46.63520404067118
F2945	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.42	-46.63
F2968	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.42	-46.63
F2977	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.42	-46.63
F3012	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.42	-46.63
F3523	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.42	-46.63
F3713	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.451890	-46.637104
F3721	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.451890	-46.637104
F3731	PE Cantareira	sp 309	*Luteostriata ernestoides* *	São Paulo	-23.451890	-46.637104
Froehlich (1956b)		sp 31	*Cratera joia*	Morretes/PR	-25.483460	-48.832020
F2100	PN Bocaina	sp 310	*Luteostriata nao-caissara Bocaina* *	São José do Barreiro	-22.7501	-44.6208
Boll et al 2019	PN Aparados da Serra	sp 311	*Luteostriata subtilis*	Cambará do Sul	-29.17795968679472	-50.0905760704664
F1315	Parnaso	sp 312	*Matuxia lila* *	Teresópolis	-22.47219469581555	-43.055074298022454
F1260	Parnaso	sp 313	*Matuxia theresopolitana* *	Teresópolis	-22.4482	-42.9834
F1274	Parnaso	sp 313	*Matuxia theresopolitana* *	Teresópolis	-22.4482	-42.9834
F2050	PN Bocaina	sp 314	*Matuxia tuxauita* *	São José do Barreiro	-22.7501	-44.6208
F3935	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F3940	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F3941	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F3954	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F3957	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F3958	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F4049	PE Desengano	sp 315	*Mimby g. n. pequena desengano* *	Santa Maria Madalena	-21.87	-41.91
F2275	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.88	-40.54
F2318	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19875	-40.53527777777778
F2421	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2426	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2463	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2468	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2479	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2517	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2520	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2525	RB Ruschi	sp 316	*Mimby g.n. bit* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2628	Parnaso	sp 317	*Mimby gen. n. goettei*	Teresópolis	-22.455277777777777	-42.9975
F2635	Parnaso	sp 317	*Mimby gen. n. goettei*	Teresópolis	-22.455277777777777	-42.9975
F4186	Parnaso	sp 317	*Mimby gen. n. goettei*	Teresópolis	-22.45638888888889	-42995
F2843	PN Bocaina	sp 318	*Mimby leopardina bocaina gen. n.* *	São José do Barreiro	-22.7501	-44.6208
F3697	PE Alberto Löfgren	sp 319	*Minipasipha gen. n. lofgren* *	São Paulo	-23.462758168233385	-46.63700659481653
Froehlich (1956b)		sp 32	*Notogynaphallia mourei*	Curitiba/PR	-25.548339	-49.313845
Froehlich (1956b)		sp 32	*Notogynaphallia*	Morretes/PR	-25.483460	-48.832020

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			mourei			
F2029	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2802	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2812	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2823	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2824	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2836	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2842	PN Bocaina	sp 320	*Naoamaga gen. n. acomunductus Bocaina*	São José do Barreiro	-22.7501	-44.6208
F2169	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F3975	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F4005	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F4012	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F4020	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F4027	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
F4087	PE Desengano	sp 321	*Nãogeobia rosea Desengano g. n.* *	Santa Maria Madalena	-21.87	-41.91
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
Negrete et al 2015		sp 322	*"Notogynaphalia" nawei*	Formosa, ARG	-26.1232097692096	-58.37347348756924
F4076	PE Desengano	sp 323	*Notogynaphallia desengano* *	Santa Maria Madalena	-21.87	-41.91
Negrete et al 2019	Isla Paulino, Berisso, Buenos Aires province	sp 324	*Notogynaphallia fortuita*		-34.83000	-57.875278
F2972	PE Cantareira	sp 325	*Notogynaphallia parcoides* *	São Paulo	-23.42	-46.63
F5748	EB Boraceia	sp 326	*Notogynaphallia pseudosexstriata* *	Salesópolis	-23.65389	-45.88917
Marques et al 2018		sp 327	*Obama allandra*	General Carneiro	-26.398203	-51.404433
F4222	Parnaso	sp 328	*Obama argus Graff 1899*	Teresópolis	-22.45638888888889	-42995
F2150	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2152	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2153	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2154	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2155	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2156	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2157	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2168	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2171	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2172	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2173	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2174	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2175	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2177	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2179	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F2181	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2182	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2183	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2209	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2216	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2217	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2218	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F2219	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3978	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3979	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3980	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3983	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3986	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F3989	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F4016	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F4042	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F4044	PE Desengano	sp 328	*Obama argus Graff 1899*	Santa Maria Madalena	-21.87	-41.91
F1242	Parnaso	sp 329	*Obama argus Schirch*	Teresópolis	-22.4482	-42.9834
F2543	Parnaso	sp 329	*Obama argus Schirch*	Teresópolis	-22.455277777777777	-42.9975
F2558	Parnaso	sp 329	*Obama argus Schirch*	Teresópolis	-22.455277777777777	-42.9975
F4188	Parnaso	sp 329	*Obama argus Schirch*	Teresópolis	-22.45638888888889	-42995
F2210	PE Desengano	sp 329	*Obama argus Schirch*	Santa Maria Madalena	-21.87	-41.91
F2211	PE Desengano	sp 329	*Obama argus Schirch*	Santa Maria Madalena	-21.87	-41.91
F3653	PE Alberto Löfgren	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.462758168233385	-46.63700659481653
F3661	PE Alberto Löfgren	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.462758168233385	-46.63700659481653
F3672	PE Alberto Löfgren	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.462758168233385	-46.63700659481653
F3683	PE Alberto Löfgren	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.462758168233385	-46.63700659481653
F3072	PE Cantareira	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.42	-46.63
F3080	PE Cantareira	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.42	-46.63
F3737	PE Cantareira	sp 33	*Notogynaphallia plumbea*	São Paulo	-23.451890	-46.637104
Froehlich (1956b)		sp 33	*Notogynaphallia plumbea*	Morretes/PR	-25.483460	-48.832020
Lago-Barcia et al., 2020 / F3085		sp 33	*Notogynaphallia plumbea*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3229		sp 33	*Notogynaphallia plumbea*	PE Tabuleiro	-27.9813889	-48.748055555
Lago-Barcia et al., 2020 / F1627		sp 33	*Notogynaphallia plumbea*	PN Saint Hilaire	-25.469604	-48.813739
Carbayo et al (2013)		sp 33	*Notogynaphallia plumbea*	Ribeirão Grande/SP	-24.27638	-48.41556
Froehlich (1956b)		sp 33	*Notogynaphallia plumbea*	São Paulo/SP	-23.459300	-46.755164
F2231	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.88	-40.54
F2251	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.88	-40.54
F2276	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.88	-40.54
F2307	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19875	-40.53527777777778
F2402	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.878611111111113	-40.53944444444444
F2412	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.878611111111113	-40.53944444444444
F2415	RB Ruschi	sp 330	*Obama burmeisteri Graff **	Santa Teresa	-19.878611111111113	-40.53944444444444
F2418	RB Ruschi	sp 330	*Obama burmeisteri*	Santa Teresa	-19.878611111111113	-40.53944444444444

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			Graff *			
F2443	RB Ruschi	sp 330	*Obama burmeisteri Graff* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2456	RB Ruschi	sp 330	*Obama burmeisteri Graff* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2461	RB Ruschi	sp 330	*Obama burmeisteri Graff* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2538	RB Ruschi	sp 330	*Obama burmeisteri Graff* *	Santa Teresa	-19.88	-40.54
F3263	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3267	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3269	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3272	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3274	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3286	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3294	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
F3323	PE Tabuleiro	sp 331	*Obama cristiana* *	Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F6530	Trilha dentro da RPPN Vale das Pedras depois do rio	sp 331	*Obama cristiana* *	Alfredo Wagner	-27.61676	-49.34754
F2147	EB Boraceia	sp 332	*Obama evelinoides* *	Salesópolis	-23.65389	-45.88917
F2808	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2810	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2818	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2819	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2820	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2832	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2835	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2838	PN Bocaina	sp 333	*Obama macacona bocaina* *	São José do Barreiro	-22.7501	-44.6208
Negrete et al 2019	Reserva Natural Punta Lara	sp 334	*Obama maculatentis*	Reserva Natural Punta Lara, ARG	-34.79276330328594	-58.009228764484234
Negrete et al 2019	Reserva Natural Punta Lara	sp 334	*Obama maculatentis*	Reserva Natural Punta Lara, ARG	-34.79276330328594	-58.009228764484234
Negrete et al 2019	Reserva Natural Punta Lara	sp 334	*Obama maculatentis*	Reserva Natural Punta Lara, ARG	-34.79276330328594	-58.009228764484234
F2041	PN Bocaina	sp 335	*Obama musgo bocaina*	São José do Barreiro	-22.7501	-44.6208
F2055	PN Bocaina	sp 335	*Obama musgo bocaina*	São José do Barreiro	-22.7501	-44.6208
F2107	PN Bocaina	sp 335	*Obama musgo bocaina*	São José do Barreiro	-22.7501	-44.6208
F2110	PN Bocaina	sp 335	*Obama musgo bocaina*	São José do Barreiro	-22.7501	-44.6208
F2315	RB Ruschi	sp 336	*Obama pretona grande* *	Santa Teresa	-19875	-40.53527777777778
F2534	RB Ruschi	sp 336	*Obama pretona grande* *	Santa Teresa	-19.88	-40.54
F2262	RB Ruschi	sp 336	*Obama pseudoapplanata* *	Santa Teresa	-19.88	-40.54
F2292	RB Ruschi	sp 336	*Obama pseudoapplanata* *	Santa Teresa	-19.904722222222222	-40.55027777777777
F2316	RB Ruschi	sp 336	*Obama pseudoapplanata* *	Santa Teresa	-19875	-40.53527777777778
F2363	RB Ruschi	sp 336	*Obama pseudoapplanata* *	Santa Teresa	-19875	-40.53527777777778
F2442	RB Ruschi	sp 336	*Obama pseudoapplanata* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F5739	EB Boraceia	sp 337	*Obama pseudocarinata* *	Salesópolis	-23.65413	-45.89514
F5750	EB Boraceia	sp 337	*Obama pseudocarinata* *	Salesópolis	-23.65389	-45.88917
F5757	EB Boraceia	sp 337	*Obama pseudocarinata* *	Salesópolis	-23.65389	-45.88917
F5781	EB Boraceia	sp 337	*Obama pseudocarinata* *	Salesópolis	-23.65389	-45.88917
F2120	EB Boraceia	sp 338	*Obama pseudoduca* *	Salesópolis	-23.65389	-45.88917
F2139	EB Boraceia	sp 338	*Obama pseudoduca* *	Salesópolis	-23.65389	-45.88917
Graff, 1899		sp 339	*Obama splendida*	Colonia Alpina (perto de Teresópolis)	-22.359416203028204	-42.96362533764643
F6528	Trilha dentro da RPPN Vale das Pedras depois do rio	sp 34	*Geoplana pulchella*	Alfredo Wagner	-27.61695	-49.34778
F6544	Trilha dentro da RPPN Vale das Pedras que	sp 34	*Geoplana pulchella*	Alfredo Wagner	-27.61696	-49.34813

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
	antecede o rio					
Almeida et al (2018)		sp 34	*Geoplana pulchella*	Alfredo Wagner/SC	-27.61695	-49.34778
Schultze & Müller (1857)		sp 34	*Geoplana pulchella*	Blumenau/SC	-27.05386	-49.08606
Almeida et al (2018)		sp 34	*Geoplana pulchella*	Paulo Lopes/SC	-27.98139	-48.74806
Marques et al 2018		sp 340	*Obama tribalis*	Gravataí	-29.885466190764628	-51.03083423404851
F2814	PN Bocaina	sp 341	*Obama ventre-caramelo bocaina* *	São José do Barreiro	-22.7501	-44.6208
F2831	PN Bocaina	sp 341	*Obama ventre-caramelo bocaina* *	São José do Barreiro	-22.7501	-44.6208
Schirch, 1929		sp 342	*Paraba bresslaui*	Teresópolis	-22.431959888773907	-43.005162984271685
Amaral et al 2019		sp 343	*Paraba pankaru*	Serra do Ramalho (BA)	-13.801069	-43.951739
F2545	Parnaso	sp 344	*Paraba pseudojoia* *	Teresópolis	-22.455277777777777	-42.9975
F2578	Parnaso	sp 344	*Paraba pseudojoia* *	Teresópolis	-22.455277777777777	-42.9975
F2582	Parnaso	sp 344	*Paraba pseudojoia* *	Teresópolis	-22.455277777777777	-42.9975
F2048	PN Bocaina	sp 345	*Paraba pseudophocaica* *	São José do Barreiro	-22.7501	-44.6208
F2827	PN Bocaina	sp 345	*Paraba pseudophocaica* *	São José do Barreiro	-22.7501	-44.6208
F2830	PN Bocaina	sp 345	*Paraba pseudophocaica* *	São José do Barreiro	-22.7501	-44.6208
F2444	RB Ruschi	sp 346	*Paraba semitaxiarcha* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2453	RB Ruschi	sp 346	*Paraba semitaxiarcha* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2460	RB Ruschi	sp 346	*Paraba semitaxiarcha* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2529	RB Ruschi	sp 346	*Paraba semitaxiarcha* *	Santa Teresa	-19.88722222222222	-40.543055555555554
AmaralZanchet2019Two new speciesferruginous and limestone cave		sp 347	*Paraba tutameia*	Cordisbugo	-19.12647077338862	-44.32499283341674
F2433	RB Ruschi	sp 348	*Paraba_linha_preta_sp_n*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2232	RB Ruschi	sp 349	*Paraba_sanguinolenta_sp_n*	Santa Teresa	-19.88	-40.54
F2381	RB Ruschi	sp 349	*Paraba_sanguinolenta_sp_n*	Santa Teresa	-19875	-40.53527777777778
Froehlich (1955b)		sp 35	*Pasipha splendida*	Teresópolis/RJ	-22.439089	-42.994351
F1331	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.49659397554616	-43.00236847415091
F1334	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.49659397554616	-43.00236847415091
F4219	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.45638888888889	-42995
F4220	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.45638888888889	-42995
F4221	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.45638888888889	-42995
F4314	Parnaso	sp 350	*Parnaso gen. n. bulbosa* *	Teresópolis	-22.45642	-42.99514
Amaral et al 2018		sp 351	*Pasipha albicaudata*	Portão	-29.681558487501363	-51.24270363395399
Amaral et al 2018		sp 351	*Pasipha albicaudata*	Salvador do sul	-29.443895902213058	-51.51443862750593
F3074	PE Cantareira	sp 352	*Pasipha atriaciliata* *	São Paulo	-23.42	-46.63
F3010	PE Cantareira	sp 353	*Pasipha chimbevoives* *	São Paulo	-23.42	-46.63
F2252	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.88	-40.54
F2291	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.904722222222222	-40.55027777777777
F2365	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19875	-40.53527777777778
F2366	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19875	-40.53527777777778
F2367	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19875	-40.53527777777778
F2368	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19875	-40.53527777777778
F2382	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19875	-40.53527777777778
F2413	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2417	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2428	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2509	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.88722222222222	-40.543055555555554

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F2519	RB Ruschi	sp 354	*Pasipha cinza c listra mediana clara* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F3977	PE Desengano	sp 355	*Pasipha cinza* *	Santa Maria Madalena	-21.87	-41.91
F4072	PE Desengano	sp 355	*Pasipha cinza* *	Santa Maria Madalena	-21.87	-41.91
F4082	PE Desengano	sp 355	*Pasipha cinza* *	Santa Maria Madalena	-21.87	-41.91
F4088	PE Desengano	sp 355	*Pasipha cinza* *	Santa Maria Madalena	-21.87	-41.91
F4090	PE Desengano	sp 355	*Pasipha cinza* *	Santa Maria Madalena	-21.87	-41.91
F4273	Parnaso	sp 356	*Pasipha cinza Teresopolis* *	Teresópolis	-22.45138888888889	-43.00138888888889
F4294	Parnaso	sp 356	*Pasipha cinza Teresopolis* *	Teresópolis	-22.45138888888889	-43.00138888888889
F4295	Parnaso	sp 356	*Pasipha cinza Teresopolis* *	Teresópolis	-22.45138888888889	-43.00138888888889
F4296	Parnaso	sp 356	*Pasipha cinza Teresopolis* *	Teresópolis	-22.45138888888889	-43.00138888888889
F2475	RB Ruschi	sp 357	*Pasipha com papila* *	Santa Teresa	-19.91222222222222	-40.53611111111111
Leal_zanchet & Marques 2018		sp 358	*Pasipha ferrariaphila*	Conceição do Mato Dentro	-18.917278	-43.428444
F2241	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19.88	-40.54
F2245	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19.88	-40.54
F2246	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19.88	-40.54
F2354	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19875	-40.53527777777778
F2357	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19875	-40.53527777777778
F2409	RB Ruschi	sp 359	*Pasipha geobioides* *	Santa Teresa	-19.878611111111113	-40.53944444444444
Froehlich, 1955		sp 36	*Pasipha oliverioi*	Teresópolis	-22.431959888773907	-43.005162984271685
F2258	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.88	-40.54
F2284	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.88	-40.54
F2317	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2327	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2355	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2371	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2372	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2373	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2374	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2375	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2376	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2377	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19875	-40.53527777777778
F2411	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2423	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2502	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2522	RB Ruschi	sp 360	*Pasipha listra preta* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F1808	PE Alberto Löfgren	sp 361	*Pasipha não pasipha* *	São Paulo	-23.462758168233385	-46.63700659481653
F2285	RB Ruschi	sp 362	*Pasipha nungara* *	Santa Teresa	-19.88	-40.54
F1876	PE Alberto Löfgren	sp 363	*Pasipha obliqua* *	São Paulo	-23.462758168233385	-46.63700659481653
F2879	PE Cantareira	sp 363	*Pasipha obliqua* *	São Paulo	-23.460277777777776	-46.63666666666666
Amaral et al 2018		sp 364	*Pasipha paucilineata*	Portão	-29.700277777777778	-50.24277777777778
Amaral et al 2018		sp 364	*Pasipha paucilineata*	Portão	-29.700277777777778	-50.24277777777778
Amaral et al 2018		sp 364	*Pasipha paucilineata*	Portão	-29.700277777777778	-50.24277777777778
F2347	RB Ruschi	sp 365	*Pasipha pinima 4*	Santa Teresa	-19875	-40.53527777777778
F3995	PE Desengano	sp 366	*Pasipha pseudomesoxantha* *	Santa Maria Madalena	-21.87	-41.91
F1259	Parnaso	sp 367	*Pasipha pseudopinima* *	Teresópolis	-22.4482	-42.9834
F2585	Parnaso	sp 367	*Pasipha pseudopinima* *	Teresópolis	-22.455277777777777	-42.9975
F2612	Parnaso	sp 367	*Pasipha pseudopinima* *	Teresópolis	-22.455277777777777	-42.9975
F2289	RB Ruschi	sp 368	*Pasipha queimada* *	Santa Teresa	-19.88	-40.54
F2488	RB Ruschi	sp 368	*Pasipha queimada* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2504	RB Ruschi	sp 368	*Pasipha queimada* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2228	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.88	-40.54
F2249	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.88	-40.54
F2325	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2340	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2341	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2342	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2343	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2344	RB Ruschi	sp 369	*Pasipha ruschiana -*	Santa Teresa	-19875	-40.53527777777778

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
			risquinhos laterais *			
F2396	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19875	-40.53527777777778
F2398	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2422	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2430	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2437	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2471	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2481	RB Ruschi	sp 369	*Pasipha ruschiana - risquinhos laterais* *	Santa Teresa	-19.88722222222222	-40.543055555555554
Froehlich (1955b)		sp 37	*"Geoplana" fragai*	Teresópolis/RJ	-22.439089	-42.994351
Amaral et al 2018		sp 370	*Pasipha variistriata*	General Carneiro	-26.398203	-51.404433
Amaral et al 2018		sp 370	*Pasipha variistriata*	General Carneiro	-26.398203	-51.404433
Amaral et al 2018		sp 370	*Pasipha variistriata*	General Carneiro	-26.398203	-51.404433
Amaral et al 2018		sp 370	*Pasipha variistriata*	General Carneiro	-26.398203	-51.404433
F2238	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88	-40.54
F2259	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88	-40.54
F2271	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88	-40.54
F2272	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88	-40.54
F2295	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.904722222222222	-40.55027777777777
F2358	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19875	-40.53527777777778
F2419	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2434	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.878611111111113	-40.53944444444444
F2490	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2515	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F2523	RB Ruschi	sp 371	*Penpasipha gen. n.* *	Santa Teresa	-19.88722222222222	-40.543055555555554
F6462	PE Pedra Branca	sp 38	*"Geoplana" jandira*	Rio de Janeiro	-22.95681	-43.44840
Froehlich (1955b)		sp 38	*"Geoplana" jandira*	Teresópolis/RJ	-22.439089	-42.994351
F5922	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.87923	-46.03430
F5924	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.88014	-46.03318
F5929	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.87785	-46.03403
F5937	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.88014	-46.03318
F5946	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.87895	-46.03409
F5957	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.87895	-46.03409
F5983	Monte Verde	sp 39	*Obama braunsi*	Camanducaia	-22.85915	-46.03035
F1080	Sítio Prof. Menna	sp 39	*Obama braunsi*	Mogi das Cruzes	-23.451536	-46.227993
F1081	Sítio Prof. Menna	sp 39	*Obama braunsi*	Mogi das Cruzes	-23.451536	-46.227993
F7035	Sítio Prof. Menna	sp 39	*Obama braunsi*	Mogi das Cruzes	-23.451536	-46.227993
Froehlich (1957)		sp 39	*Obama braunsi*	Amparo/SP	-22.682420	-46.732935
Marcus (1951)		sp 39	*Obama braunsi*	Mogi das Cruzes/SP	-23.505856	-46.211903
Graff (1899)		sp 39	*Obama braunsi*	Santos/SP	-23.87	-46.32
Graff (1899)		sp 39	*Obama braunsi*	São Paulo/SP	-23.459300	-46.755164
Leal-Zanchet et al (2011)		sp 4	*Luteostriata ceciliae*	Cambará do Sul/RS	-29.179104	-50.080631
Froehlich & Leal-Zanchet, 2003		sp 4	*Luteostriata ceciliae*	São Francisco de Paula/RS	-29.428944	-50.392000
Froehlich (1957)		sp 40	*Paraba caapora*	Apiaí/SP	-24.518261	-48.844379
Lago-Barcia et al., 2020 / F4624		sp 40	*Paraba caapora*	PN Itajaí	-27.05386	-49.08606
Froehlich (1957)		sp 41	*Obama poca*	Itanhaém/SP	-24.148182	-46.830256
Froehlich (1957)		sp 42	*Obama schubarti*	São Paulo/SP	-23.459300	-46.755164
FroehlichCG_1957_On a collection of Brazilian Land Planarians	Tapirai, a sm all village ca. 100 km. W SW of the city of São Paulo, betw een Piedade and Juquiá	sp 43	*Paraba tapira*	Tapiraí – SP	-23.962859168189137	-47.51106780643493
Lago-Barcia et al., 2020 / F3797		sp 43	*Paraba tapira*	PE Intervales	-24.269387	-48.405467
Froehlich (1957)		sp 43	*Paraba tapira*	Tapiraí/SP	-23.964151	-47.512885
Froehlich (1957)		sp 44	*"Geoplana" toriba*	Juquiá/SP	-24.317073	-47.639867
Lago-Barcia et al., 2020 / F3136	Intervales	sp 45	*Issoca potyra*	PE Intervales	-24.269387	-48.405467
Froehlich (1957)		sp 45	*Issoca potyra*	Eldorado/SP	-24.498352	-48.103028
Lago-Barcia et al., 2020 / F7380		sp 46	*Obama ficki*	PN São Joaquim	-28.235930	-49.498947
Amaral et al (2012)		sp 46	*Obama ficki*	Praia Grande/SC	-29.198086	-50.026672
Amaral et al (2014)		sp 46	*Obama ficki*	Salvador do Sul/RS	-29.442428	-51.502151
Amaral et al (2012)		sp 46	*Obama ficki*	São Francisco de Paula/RS	-29.428944	-50.392000

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Lago-Barcia et al., 2020 / F7258		sp 47	*Obama sp. 14*	PN São Joaquim	-28.156986	-49.637516
Lago-Barcia et al., 2020 / F7372		sp 48	*Cratera sp. 5*	PN São Joaquim	-28.162100	-49.626466
Marcus, 1951	Cidade Jardim	sp 49	*Paraba preta*	São Paulo	-23.542487525138924	-46.614574045241795
Riester (1938)		sp 49	*Paraba preta*	Teresópolis/RJ	-22.439089	-42.994351
Schultze & Müller (1857)		sp 5	*Obama marmorata*	Blumenau/SC	-27.05386	-49.08606
Carbayo et al (2016)		sp 5	*Obama marmorata*	Paulo Lopes/SC	-27.84278	-48.92583
Carbayo et al (2016)		sp 5	*Obama marmorata*	Paulo Lopes/SC	-27.95869	-48.76164
Lago-Barcia et al., 2020 / F4620		sp 5	*Obama marmorata*	PN Itajaí	-27.05386	-49.08606
Lago-Barcia et al., 2020 / F7401		sp 5	*Obama marmorata*	PN São Joaquim	-28.235882	-49.498872
Froehlich (1959)		sp 5	*Obama marmorata*	Rio do Testo/SC	-26.743720	-49.175644
Carbayo et al (2016)		sp 5	*Obama marmorata*	São Bonifácio/SC	-27.84278	-48.92583
F7904	Em volta da casa FC	sp 50	*Geobia subterranea*	Atibaia	-23.221727	-46.550084
F0022	Mata do Instituto de Biociências - USP	sp 50	*Geobia subterranea*	São Paulo	-23.56566110327161	-46.73040002995005
F0681	Paranapiacaba	sp 50	*Geobia subterranea*	Santo André	-23.779001	-46.300616
F1124	Parnaso	sp 50	*Geobia subterranea*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1140	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.45642	-42.99514
F1141	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.45642	-42.99514
F1231	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1248	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1251	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1252	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1253	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1254	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1257	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1270	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.4482	-42.9834
F1309	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.47219469581555	-43.055074298022454
F1312	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.47219469581555	-43.055074298022454
F1355	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1356	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1357	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1358	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1359	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1360	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1361	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1362	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1364	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1365	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1366	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1368	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1370	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1376	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1377	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1379	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1380	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1381	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1382	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F1383	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.49659397554616	-43.00236847415091
F2597	Parnaso	sp 50	*Geobia subterranea*	Teresópolis	-22.455277777777777	-42.9975
F5231	Parque do Carmo	sp 50	*Geobia subterranea*	São Paulo	-23.576206711512366	-46.46234439668165
Marcus, 1951	Parque paulista	sp 50	*Geobia subterranea*	São Paulo	-23.542487525138924	-46.614574045241795
F1766	PE Alberto Löfgren	sp 50	*Geobia subterranea*	São Paulo	-23.462758168233385	-46.63700659481653
F1911	PE Alberto Löfgren	sp 50	*Geobia subterranea*	São Paulo	-23.462758168233385	-46.63700659481653
F2024	PE Cantareira	sp 50	*Geobia subterranea*	São Paulo	-23.435798019670848	-46.63520404067118
F2947	PE Cantareira	sp 50	*Geobia subterranea*	São Paulo	-23.42	-46.63
F3734	PE Cantareira	sp 50	*Geobia subterranea*	São Paulo	-23.451890	-46.637104
F6285	PN Tijuca	sp 50	*Geobia subterranea*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6286	PN Tijuca	sp 50	*Geobia subterranea*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6349	PN Tijuca	sp 50	*Geobia subterranea*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F0510	Pq da Previdência	sp 50	*Geobia subterranea*	São Paulo	-23.580206	-46.727321
F0511	Pq da Previdência	sp 50	*Geobia subterranea*	São Paulo	-23.580206	-46.727321
F2432	RB Ruschi	sp 50	*Geobia subterranea*	Santa Teresa	-19.878611111111113	-40.53944444444444
F0452	Reserva ambiental Hering Têxtil S/	sp 50	*Geobia subterranea*	Blumenau	-26.911207756993	-49.086718444235096

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
	A					
F7073	Sítio Prof. Menna	sp 50	*Geobia subterranea*	Mogi das Cruzes	-23.451536	-46.227993
Marcus, 1951		sp 50	*Geobia subterranea*	Avaré	-23.09794250036244	-48.943756995606975
Marcus (1951)		sp 50	*Geobia subterranea*	Avaré/SP	-23.096206	-48.914060
Schultze & Müller (1857)		sp 50	*Geobia subterranea*	Blumenau/SC	-27.05386	-49.08606
Marcus, 1951		sp 50	*Geobia subterranea*	Mogi das Cruzes	-23.55252443748352	-46.1700868316946
Marcus (1951)		sp 50	*Geobia subterranea*	Mogi das Cruzes/SP	-23.505856	-46.211903
Lago-Barcia et al., 2020 / F3608		sp 50	*Geobia subterranea*	Saint-Hilaire	-25.71	-48.62
Carbayo et al (2013)		sp 50	*Geobia subterranea*	São Leopoldo/RS	-29.764171	-51.155840
CG Froehlich (1955)		sp 50	*Geobia subterranea*	São Paulo/SP	-23.448030	-46.666767
Riester (1938)		sp 50	*Geobia subterranea*	Teresópolis/RJ	-22.439089	-42.994351
F2137	EB Boraceia	sp 51	*Choeradoplana marthae*	Salesópolis	-23.65389	-45.88917
F5790	EB Boraceia	sp 51	*Choeradoplana marthae*	Salesópolis	-23.65389	-45.88917
CG Froehlich (1955)		sp 51	*Choeradoplana marthae*	Mongaguá/SP	-24.085174	-46.640241
F2338	RB Ruschi	sp 52	*Xerapoa ruschi* *	Santa Teresa	-19875	-40.53527777777778
F2441	RB Ruschi	sp 52	*Xerapoa ruschi* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2452	RB Ruschi	sp 52	*Xerapoa ruschi* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F2472	RB Ruschi	sp 52	*Xerapoa ruschi* *	Santa Teresa	-19.91222222222222	-40.53611111111111
F5884	EcoPark Aruã	sp 53	*Issoca rezendei*	Mogi das Cruzes	-23.46273	-46.26598
F6658	Fazenda Loanda, terreno baldio	sp 53	*Issoca rezendei*	Bananal	-22.678586	-44.225681
F6667	Fazenda Loanda, terreno baldio	sp 53	*Issoca rezendei*	Bananal	-22.678586	-44.225681
F0024	Mata do Instituto de Biociências - USP	sp 53	*Issoca rezendei*	São Paulo	-23.56566110327161	-46.73040002995005
F1120	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1121	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1129	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1130	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1131	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1132	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1133	Parnaso	sp 53	*Issoca rezendei*	Ao lado de Petrópolis	-22.461575502209527	-43.09364118764476
F1332	Parnaso	sp 53	*Issoca rezendei*	Teresópolis	-22.49659397554616	-43.00236847415091
F1369	Parnaso	sp 53	*Issoca rezendei*	Teresópolis	-22.49659397554616	-43.00236847415091
F1372	Parnaso	sp 53	*Issoca rezendei*	Teresópolis	-22.49659397554616	-43.00236847415091
F1753	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1757	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1759	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1781	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1785	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1790	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1791	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1792	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1795	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1796	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1797	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1798	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1801	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1802	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F1812	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1828	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1852	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1857	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1858	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1859	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1860	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1861	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1867	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1868	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1869	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1870	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1874	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1909	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1918	PE Alberto Löfgren	sp 53	*Issoca rezendei*	São Paulo	-23.462758168233385	-46.63700659481653
F1946	PE Cantareira	sp 53	*Issoca rezendei*	São Paulo	-23.435798019670848	-46.63520404067118
F2877	PE Cantareira	sp 53	*Issoca rezendei*	São Paulo	-23.460277777777776	-46.63666666666666
F1159	Pq da Previdência	sp 53	*Issoca rezendei*	São Paulo	-23.579662	-46.727503
F1160	Pq da Previdência	sp 53	*Issoca rezendei*	São Paulo	-23.579662	-46.727503
F1175	Pq da Previdência	sp 53	*Issoca rezendei*	São Paulo	-23.579662	-46.727503
F1176	Pq da Previdência	sp 53	*Issoca rezendei*	São Paulo	-23.579662	-46.727503
F6834	Pq da Previdência	sp 53	*Issoca rezendei*	São Paulo	-23.580206	-46.727321
F2242	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.88	-40.54
F2247	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.88	-40.54
F2267	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.88	-40.54
F2300	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2302	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2305	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2324	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2334	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2362	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19875	-40.53527777777778
F2425	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2435	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2436	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.878611111111113	-40.53944444444444
F2440	RB Ruschi	sp 53	*Issoca rezendei*	Santa Teresa	-19.878611111111113	-40.53944444444444
CG Froehlich (1955)		sp 53	*Issoca rezendei*	Blumenau/SC	-27.05386	-49.08606
CG Froehlich (1955)		sp 53	*Issoca rezendei*	Itajaí/SC	-26.957485	-48.756133
CG Froehlich (1955)		sp 53	*Issoca rezendei*	Itanhaém/SP	-24.148182	-46.830256
CG Froehlich (1955)		sp 53	*Issoca rezendei*	Mongaguá/SP	-24.085174	-46.640241
Lago-Barcia et al., 2020 / F3595		sp 53	*Issoca rezendei*	Saint-Hilaire	-25.469604	-48.813739
Marcus (1951)		sp 53	*Issoca rezendei*	São Paulo/SP	-23.578104	-46.689043
Schirch (1929)		sp 53	*Issoca rezendei*	Teresópolis/RJ	-22.500057	-42.997365
CG Froehlich (1955)		sp 53	*Issoca rezendei*	Ubatuba/SP	-23.423381	-45.083399
Carbayo et al (2013)		sp 54	*Issoca jandaia*	São José do Barreiro/SP	-22.78222	-44.60583
CG Froehlich (1955)		sp 55	*Issoca piranga*	Teresópolis/RJ	-22.439089	-42.994351
F2983	PE Cantareira	sp 56	*Xerapoa hystrix*	São Paulo	-23.42	-46.63
F3057	PE Cantareira	sp 56	*Xerapoa hystrix*	São Paulo	-23.42	-46.63
F3073	PE Cantareira	sp 56	*Xerapoa hystrix*	São Paulo	-23.42	-46.63
F3743	PE Cantareira	sp 56	*Xerapoa hystrix*	São Paulo	-23.451890	-46.637104
CG Froehlich (1955)		sp 56	*Xerapoa hystrix*	Curitiba/PR	-25.548339	-49.313845
CG Froehlich (1955)		sp 56	*Xerapoa hystrix*	Mogi das Cruzes/SP	-23.505856	-46.211903
CG Froehlich		sp 56	*Xerapoa hystrix*	São Paulo/SP	-23.453148	-46.634488

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
(1955)						
CG Froehlich (1955)		sp 57	*Xerapoa una*	Brusque/SC	-27.111325	-48.895427
F1232	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1234	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1240	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1241	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1247	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1250	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1261	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1262	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1264	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1267	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.4482	-42.9834
F1304	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.47219469581555	-43.055074298022454
F1329	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.49659397554616	-43.00236847415091
F1371	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.49659397554616	-43.00236847415091
F2544	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2564	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2566	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2567	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2571	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2575	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2576	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2579	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2581	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2583	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2587	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2588	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2589	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2596	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2606	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2607	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2610	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2611	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2614	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2621	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2629	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2630	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2631	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2632	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F2633	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.455277777777777	-42.9975
F4187	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45638888888889	-42995
F4195	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45638888888889	-42995
F4203	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45638888888889	-42995
F4212	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45638888888889	-42995
F4216	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45638888888889	-42995
F4254	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4255	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4256	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4263	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4266	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4268	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4269	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4276	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4278	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4282	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4283	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4292	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45138888888889	-43.00138888888889
F4319	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45642	-42.99514
F4321	Parnaso	sp 58	*Obama applanata*	Teresópolis	-22.45642	-42.99514
CG Froehlich (1956a)		sp 58	*Obama applanata*	Teresópolis/RJ	-22.439089	-42.994351
F5911	EcoPark Aruã	sp 59	*Notogynaphallia sexstriata*	Mogi das Cruzes	-23.46426	-46.26573
Carbayo et al (2013)		sp 59	*Notogynaphallia sexstriata*	Blumenau/SC	-27.04836	-49.09200
du Bois Reymond-Marcus (1951)		sp 59	*Notogynaphallia sexstriata*	Brusque/SC	-27.111325	-48.895427
Lago-Barcia et al., 2020 / F1413		sp 59	*Notogynaphallia sexstriata*	PNItajai	-27.05306	-49.08528
Lago-Barcia et al., 2020 / F1741		sp 59	*Notogynaphallia sexstriata*	Saint-Hilaire	-25.469604	-48.813739
Carbayo et al (2013)		sp 59	*Notogynaphallia sexstriata*	São Paulo/SP	-23.56671	-46.73017
du Bois Reymond-Marcus (1951)		sp 59	*Notogynaphallia sexstriata*	Taquara/RS	-29.659801	-50.779542
CG Froehlich (1956a)		sp 59	*Notogynaphallia sexstriata*	Teresópolis/RJ	-22.439089	-42.994351
Schultze & Müller (1857)		sp 6	*Luteostriata muelleri*	Blumenau/SC	-27.05386	-49.08606
Froehlich (1959)		sp 6	*Luteostriata muelleri*	Brusque/SC	-27.111325	-48.895427
Carbayo (2010)		sp 6	*Luteostriata muelleri*	Itajaí/SC	-26.88	-48.66

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Carbayo (2010)		sp 6	*Luteostriata muelleri*	Navegantes/SC	-26.85	-48.69
Lago-Barcia et al., 2020 / F3284		sp 6	*Luteostriata muelleri*	PE Tabuleiro	-27.840735	-48.924866
Carbayo (2010)		sp 6	*Luteostriata muelleri*	Penha/SC	-26.80	-48.65
Lago-Barcia et al., 2020 / F1588		sp 6	*Luteostriata muelleri*	PN Itajaí	-27.05306	-49.08528
Froehlich (1959)		sp 6	*Luteostriata muelleri*	Rio do Testo/SC	-26.743720	-49.175644
Carbayo et al (2013)		sp 6	*Luteostriata muelleri*	São Bonifácio/SC	-27.84278	-48.92583
Schirch (1929)		sp 60	*Paraba goettei*	Teresópolis/RJ	-22.439089	-42.994351
EMF 1955	Parnaso	sp 61	*Pasipha plana*	Teresópolis	-22.431959888773907	-43.005162984271685
F6397	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93398	-43.44228
F6415	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93713	-43.46074
F6436	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93781	-43.46202
F6437	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93409	-43.45163
F6439	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95708	-43.44801
F6442	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95708	-43.44801
F6453	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95681	-43.44840
F6454	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95681	-43.44840
F6463	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95681	-43.44840
F6470	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.95681	-43.44840
F6481	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93738	-43.46145
F6484	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93398	-43.44793
F6491	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93738	-43.46145
F6499	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93738	-43.46145
F6505	PE Pedra Branca	sp 61	*Pasipha plana*	Rio de Janeiro	-22.93738	-43.46145
Schirch (1929)		sp 61	*Pasipha plana*	Teresópolis/RJ	-22.439089	-42.994351
F1238	Parnaso	sp 62	*Cratera pseudovaginuloides*	Teresópolis	-22.4482	-42.9834
F1244	Parnaso	sp 62	*Cratera pseudovaginuloides*	Teresópolis	-22.4482	-42.9834
F1245	Parnaso	sp 62	*Cratera pseudovaginuloides*	Teresópolis	-22.4482	-42.9834
F4180	Parnaso	sp 62	*Cratera pseudovaginuloides*	Teresópolis	-22.45638888888889	-42995
F6441	PE Pedra Branca	sp 62	*Cratera pseudovaginuloides*	Rio de Janeiro	-22.95708	-43.44801
F6446	PE Pedra Branca	sp 62	*Cratera pseudovaginuloides*	Rio de Janeiro	-22.95681	-43.44840
F6459	PE Pedra Branca	sp 62	*Cratera pseudovaginuloides*	Rio de Janeiro	-22.95681	-43.44840
Riester (1938)		sp 62	*Cratera pseudovaginuloides*	Teresópolis/RJ	-22.439089	-42.994351
Froehlich 1956TricladiaTere Ubat	Gávea Pequena	sp 63	*Luteostriata caissara*	Rio de Janeiro	-22.944308537415026	-43.24652295346541
F1266	Parnaso	sp 63	*Luteostriata caissara*	Teresópolis	-22.4482	-42.9834
F1321	Parnaso	sp 63	*Luteostriata caissara*	Teresópolis	-22.49659397554616	-43.00236847415091
F1322	Parnaso	sp 63	*Luteostriata caissara*	Teresópolis	-22.49659397554616	-43.00236847415091
F1325	Parnaso	sp 63	*Luteostriata caissara*	Teresópolis	-22.49659397554616	-43.00236847415091
F1367	Parnaso	sp 63	*Luteostriata caissara*	Teresópolis	-22.49659397554616	-43.00236847415091
CG Froehlich (1956a)		sp 63	*Luteostriata caissara*	Rio de Janeiro/RJ	-22.975852	-43.292230
CG Froehlich (1956a)		sp 63	*Luteostriata caissara*	Teresópolis/RJ	-22.439089	-42.994351
CG Froehlich (1956a)		sp 63	*Luteostriata caissara*	Teresópolis/RJ	-22.500057	-42.997365
EMF 1955	Parnaso	sp 64	*Paraba cassula*	Teresópolis	-22.431959888773907	-43.005162984271685
CG Froehlich (1956a)		sp 64	*Paraba cassula*	Teresópolis/RJ	-22.439089	-42.994351
F1062	EB Boraceia	sp 65	*Matuxia matuta*	Salesópolis	-23.65389	-45.88917
F1065	EB Boraceia	sp 65	*Matuxia matuta*	Salesópolis	-23.65389	-45.88917
F1074	EB Boraceia	sp 65	*Matuxia matuta*	Salesópolis	-23.65389	-45.88917
F2187	PE Desengano	sp 65	*Matuxia matuta*	Santa Maria Madalena	-21.87	-41.91
F2223	PE Desengano	sp 65	*Matuxia matuta*	Santa Maria Madalena	-21.87	-41.91

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F5162	PN Itatiaia	sp 65	*Matuxia matuta*	Resende	-22.454444444444444	-44.60777777777778
F5181	PN Itatiaia	sp 65	*Matuxia matuta*	Resende	-22.454444444444444	-44.60777777777778
F1116	PN Itatiaia - Km 08 - Sítio Piporaoca	sp 65	*Matuxia matuta*	Rio de Janeiro	-22.4744673237292	-44.5798137567613
Carbayo et al (2017)		sp 65	*Matuxia matuta*	Santa Maria Madalena/RJ	-21.87	-41.91
EMF 1955		sp 65	*Matuxia matuta*	Teresópolis	-22.431959888773907	-43.005162984271685
CG Froehlich (1956a)		sp 65	*Matuxia matuta*	Teresópolis/RJ	-22.439089	-42.994351
F1139	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.45642	-42.99514
F1258	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.4482	-42.9834
F1271	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.4482	-42.9834
F1336	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.49659397554616	-43.00236847415091
F2540	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2541	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2546	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2549	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2551	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2555	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2556	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2565	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2569	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2570	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2580	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2593	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2619	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2624	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F2626	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.455277777777777	-42.9975
F4197	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.45638888888889	-42995
F4200	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.45638888888889	-42995
F4253	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.45138888888889	-43.00138888888889
F4293	Parnaso	sp 66	*Cratera tamoia*	Teresópolis	-22.45138888888889	-43.00138888888889
F6434	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.93781	-43.46202
F6444	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95708	-43.44801
F6452	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95681	-43.44840
F6455	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95681	-43.44840
F6464	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95681	-43.44840
F6475	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95789	-43.44675
F6488	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.93738	-43.46145
F6501	PE Pedra Branca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.93738	-43.46145
F6220	PN Tijuca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95585	-43.27996
F6228	PN Tijuca	sp 66	*Cratera tamoia*	Rio de Janeiro	-22.95587	-43.27998
EMF 1955		sp 66	*Cratera tamoia*	Teresópolis	-22.431959888773907	-43.005162984271685
Carbayo et al (2016)		sp 66	*Cratera tamoia*	Teresópolis/RJ	-22.46447	-43.00278
CG Froehlich (1956a)		sp 66	*Cratera tamoia*	Teresópolis/RJ	-22.439089	-42.994351
CG Froehlich (1956a)		sp 66	*Cratera tamoia*	Teresópolis/RJ	-22.500057	-42.997365
CG Froehlich (1956a)		sp 67	*Obama trigueira*	Teresópolis/RJ	-22.500057	-42.997365
EMF 1955		sp 68	*Cratera yara*	Teresópolis	-22.431959888773907	-43.005162984271685
Lago-Barcia et al., 2020 / F6897		sp 69	*Pasipha sp. 7*	Saint-Hilaire	-25.469604	-48.813739
Carbayo (2010)		sp 7	*Luteostriata abundans*	Barra do Ribeiro/RS	-30.31	-51.32
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Campo Bom/RS	-29.67	-51.06
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Glorinha/RS	-29.88	-50.79
Carbayo 2010		sp 7	*Luteostriata abundans*	Nova Petrópolis	-29.3801661149462	-51.11328345889508
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Novo Hamburgo/RS	-29.72	-51.12
Carbayo et al (2013)		sp 7	*Luteostriata abundans*	Parobé/RS	-29.62940	-50.83110
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Poço das Antas/RS	-29.44	-51.68
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Salvador do Sul/RS	-29.442428	-51.502151
Carbayo et al (2013)		sp 7	*Luteostriata abundans*	São Leopoldo/RS	-29.78828	-51.15084
Froehlich (1959)		sp 7	*Luteostriata abundans*	São Leopoldo/RS	-29.764171	-51.155840
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Taquara/RS	-29.659801	-50.779542

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Amaral et al (2014)		sp 7	*Luteostriata abundans*	Tupandi/RS	-29.47	-51.42
Antunes et al (2008)		sp 7	*Luteostriata abundans*	Viamão/RS	-30.345738	-51.027817
CG Froehlich (1956a)		sp 70	*Rhynchodemus hectori*	Teresópolis/RJ	-22.439089	-42.994351
F1328	Parnaso	sp 71	*Barreirana barreirana*	Teresópolis	-22.49659397554616	-43.00236847415091
F6403	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93453	-43.44106
F6405	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93460	-43.44107
F6417	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93928	-43.46373
F6418	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.932864443613017	-4344234887533700
F6420	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93568	-43.45579
F6422	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97116	-43.43689
F6423	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97116	-43.43689
F6424	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97116	-43.43689
F6425	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97116	-43.43689
F6426	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97121	-43.44009
F6427	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.97116	-43.43689
F6472	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.96793	-43.44414
F6790	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93742	-043.46179
F6797	PE Pedra Branca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.93720	-043.46122
F6284	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6291	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6293	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6303	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6305	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6326	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6328	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6333	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
F6341	PN Tijuca	sp 71	*Barreirana barreirana*	Rio de Janeiro	-22.95166393342824	-43.27725815654048
CG Froehlich (1956a)		sp 71	*Barreirana barreirana*	Rio de Janeiro/RJ	-22.975852	-43.292230
Riester (1938)		sp 71	*Barreirana barreirana*	Teresópolis/RJ	-22.500057	-42.997365
CG Froehlich (1956a)		sp 71	*Barreirana barreirana*	Ubatuba/SP	-23.423381	-45.083399
Riester (1938)		sp 72	*Barreirana zebroides*	Teresópolis/RJ	-22.500057	-42.997365
Marcus, 1951	Horto florestal	sp 73	*Cratera taxiarcha*	Mogi das Cruzes	-23.55252443748352	-46.1700868316946
F0680	Paranapiacaba	sp 73	*Cratera taxiarcha*	Santo André	-23.779001	-46.300616
F1849	PE Alberto Löfgren	sp 73	*Cratera taxiarcha*	São Paulo	-23.462758168233385	-46.63700659481653
F2921	PE Cantareira	sp 73	*Cratera taxiarcha*	São Paulo	-23.460277777777776	-46.63666666666666
F2926	PE Cantareira	sp 73	*Cratera taxiarcha*	São Paulo	-23.460277777777776	-46.63666666666666
F2928	PE Cantareira	sp 73	*Cratera taxiarcha*	São Paulo	-23.460277777777776	-46.63666666666666
F3518	PE Cantareira	sp 73	*Cratera taxiarcha*	São Paulo	-23.42	-46.63
F3519	PE Cantareira	sp 73	*Cratera taxiarcha*	São Paulo	-23.42	-46.63
F6157	Pq Mun Nasc Paranapiacaba	sp 73	*Cratera taxiarcha*	Santo André	-23.77942132451774	-46.29898242952317
F4969	ReBioMun Serra Japi	sp 73	*Cratera taxiarcha*	Jundiaí	-23.23153	-46.93550
Marcus (1951)		sp 73	*Cratera taxiarcha*	São Paulo/SP	-23.453148	-46.634488
CG Froehlich (1956a)		sp 74	*Pasipha cafusa*	Ubatuba/SP	-23.423381	-45.083399
CG Froehlich (1956a)		sp 75	*"Geoplana" picta*	Ubatuba/SP	-23.423381	-45.083399
CG Froehlich (1956a)		sp 76	*Rhynchodemus scius*	Ubatuba/SP	-23.423381	-45.083399
EMF 1955	Morro jaraguá	sp 77	*Pasipha chimbeva*	São Paulo	-23.45865446921073	-46.760200364117026
F2797	PN Bocaina	sp 77	*Pasipha chimbeva*	São José do Barreiro	-22.7501	-44.6208
EM Froehlich (1955a)		sp 78	*"Geoplana" chiuna*	Pirassununga/SP	-22.007522	-47.459448
F3618	PE Alberto Löfgren	sp 79	*Cratera crioula*	São Paulo	-23.462758168233385	-46.63700659481653
Araujo et al 2020	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.44416307180465	-46.63846833766449
EMF 1955	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.44416307180465	-46.63846833766449
F2946	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2960	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2963	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2988	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F2989	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2990	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2991	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2992	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F2993	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3019	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3024	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3529	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3532	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3537	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3549	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3552	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3557	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.42	-46.63
F3709	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3712	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3715	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3723	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3725	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3727	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3728	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3735	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3738	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3739	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3744	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3745	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
F3746	PE Cantareira	sp 79	*Cratera crioula*	São Paulo	-23.451890	-46.637104
EM Froehlich (1955a)		sp 79	*Cratera crioula*	São Paulo/SP	-23.453148	-46.634488
Marcus (1951)		sp 8	*"Geoplana" carrierei sensu Marcus 1951*	Santo André/SP	-23.773397	-46.333248
Froehlich (1959)		sp 8	*"Geoplana" carrierei sensu Marcus 1951*	São Leopoldo/RS	-29.764171	-51.155840
Marcus (1951)		sp 8	*"Geoplana" carrierei sensu Marcus 1951*	São Paulo/SP	-23.561966	-46.656958
EMF 1955	Morro jaraguá	sp 80	*Obama livia*	São Paulo	-23.45865446921073	-46.760200364117026
EM Froehlich (1955a)		sp 80	*Obama livia*	São Paulo/SP	-23.453148	-46.634488
EM Froehlich (1955a)		sp 80	*Obama livia*	São Paulo/SP	-23.459736	-46.761403
EMF 1955	PE Cantareira	sp 81	*Notogynaphallia parca*	São Paulo	-23.44416307180465	-46.63846833766449
F5232	PE Cantareira	sp 81	*Notogynaphallia parca*	São Paulo	-23.42	-46.63
Lago-Barcia et al., 2020 / F2752		sp 82	*Pasipha pinima*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F7296		sp 82	*Pasipha pinima*	PN São Joaquim	-28.041154	-49.615693
EM Froehlich (1955a)		sp 82	*Pasipha pinima*	São Paulo/SP	-23.453148	-46.634488
EM Froehlich (1955a)		sp 83	*"Geoplana" regia*	Araraquara/SP	-21.779764	-48.161178
EMF 1955	Morro jaraguá	sp 84	*Matuxia tuxaua*	São Paulo	-23.45865446921073	-46.760200364117026
F1233	Parnaso	sp 84	*Matuxia tuxaua*	Teresópolis	-22.4482	-42.9834
F1275	Parnaso	sp 84	*Matuxia tuxaua*	Teresópolis	-22.4482	-42.9834
F2985	PE Cantareira	sp 84	*Matuxia tuxaua*	São Paulo	-23.42	-46.63
F3059	PE Cantareira	sp 84	*Matuxia tuxaua*	São Paulo	-23.45	-46.63
F6506	PE Pedra Branca	sp 84	*Matuxia tuxaua*	Rio de Janeiro	-22.93738	-43.46145
F2105	PN Bocaina	sp 84	*Matuxia tuxaua*	São José do Barreiro	-22.7501	-44.6208
F2795	PN Bocaina	sp 84	*Matuxia tuxaua*	São José do Barreiro	-22.7501	-44.6208
EM Froehlich (1955a)		sp 84	*Matuxia tuxaua*	São Paulo/SP	-23.453148	-46.634488
EM Froehlich (1955a)		sp 84	*Matuxia tuxaua*	São Paulo/SP	-23.459736	-46.761403
Carbayo et al (2013)		sp 84	*Matuxia tuxaua*	Teresópolis/RJ	-22.45528	-42.99750
Riester (1938)		sp 85	*"Geoplana" ferussaci sensu Riester 1938*	Nova Lima/MG	-20.02	-43.91
Marcus (1951)		sp 85	*"Geoplana" ferussaci sensu Riester 1938*	São Paulo/SP	-23.500212	-46.702310
Riester (1938)		sp 85	*"Geoplana" ferussaci sensu Riester 1938*	Teresópolis/RJ	-22.500057	-42.997365
F6621	Vila de Paranapiacaba e caminho de acesso	sp 86	*Obama metzi*	Santo André	-23.779001	-46.300616
Riester (1938)		sp 86	*Obama metzi*	Ribeirão Pires/SP	-23.701329	-46.39
Marcus (1951)		sp 86	*Obama metzi*	São Paulo/SP	-23.500212	-46.702310
Marcus (1951)		sp 87	*Imbira marcusi*	Mogi das Cruzes/SP	-23.505856	-46.211903
Marcus (1951)		sp 87	*Imbira marcusi*	Mongaguá/SP	-24.085174	-46.640241
Lago-Barcia et al., 2020 / F3161		sp 87	*Imbira marcusi*	PE Intervales	-24.269387	-48.405467
Lago-Barcia et al., 2020 / F3568		sp 87	*Imbira marcusi*	PN Saint Hilaire	-25.469604	-48.813739

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
Álvarez-PResas et al (2011)		sp 87	*Imbira marcusi*	São José do Barreiro/SP	-22.72583	-44.62611
Marcus (1951)		sp 87	*Imbira marcusi*	São Paulo/SP	-23.500212	-46.702310
Marcus, 1951	Cidade Jardim	sp 88	*Pasipha astraea*	São Paulo	-23.542487525138924	-46.614574045241795
Marcus (1951)		sp 88	*Pasipha astraea*	São Paulo/SP	-23.500212	-46.702310
Marcus, 1951	Alto da Serra	sp 89	*Obama divae*	Santo André	-23.77591085738422	-46.32020141303849
F6546	Trilha dentro da RPPN Vale das Pedras que antecede o rio	sp 9	*Obama ladislavii*	Alfredo Wagner	-27.61736	-49.35113
Lago-Barcia et al., 2020 / F6545	Trilha dentro da RPPN Vale das Pedras que antecede o rio	sp 9	*Obama ladislavii*	Alfredo Wagner	-27.61736	-49.35113
Lago-Barcia et al., 2020 / F6545		sp 9	*Obama ladislavii*	Alfredo Wagner	-24.61695	-49.35075
Castro & Leal_Zanchet (2005)		sp 9	*Obama ladislavii*	Arroio Grande/RS	-29.672918	-53.668858
Graff (1899)		sp 9	*Obama ladislavii*	Blumenau/SC	-27.05386	-49.08606
Baptista et al (2006)		sp 9	*Obama ladislavii*	Cambará do Sul/RS	-29.179104	-50.080631
Álvarez-Presas et al (2015)		sp 9	*Obama ladislavii*	Montenegro/RS	-29.688889	-51.466944
Lago-Barcia et al., 2020 / F3262		sp 9	*Obama ladislavii*	PE Tabuleiro	-27.840735	-48.924866
Lago-Barcia et al., 2020 / F7357		sp 9	*Obama ladislavii*	PN São Joaquim	-28.038956	-49.614243
Amaral et al (2014)		sp 9	*Obama ladislavii*	Salvador do Sul/RS	-29.442428	-51.502151
Álvarez-Presas et al (2015)		sp 9	*Obama ladislavii*	São Bonifácio/SC	-27.84278	-48.92583
Antunes et al (2012)		sp 9	*Obama ladislavii*	São Francisco de Paula/RS	-29.428944	-50.392000
Froehlich (1959)		sp 9	*Obama ladislavii*	São Leopoldo/RS	-29.764171	-51.155840
Graff (1899)		sp 9	*Obama ladislavii*	Taquara/RS	-29.659801	-50.779542
Antunes et al (2008)		sp 9	*Obama ladislavii*	Viamão/RS	-30.345738	-51.027817
Marcus, 1951	Horto Florestal	sp 90	*Obama duca*	Mogi das Cruzes	-23.55252443748352	-46.1700868316946
Marcus (1951)		sp 90	*Obama duca*	Mogi das Cruzes/SP	-23.505856	-46.211903
Marcus (1951)		sp 90	*Obama duca*	São Paulo/SP	-23.453148	-46.634488
F4405	Sertão do Cambury (região da casa Menna)	sp 91	*Obama evelinae*	São Sebastião	-23.75203	-45.63103
F6629	Vila de Paranapiacaba	sp 91	*Obama evelinae*	Santo André	-23.779001	-46.300616
Marcus, 1951		sp 91	*Obama evelinae*	Mongaguá	-24.08746949766262	-46.69906869533267
Marcus (1951)		sp 91	*Obama evelinae*	Mongaguá/SP	-24.085174	-46.640241
Marcus (1951)		sp 91	*Obama evelinae*	Santo André/SP	-23.773397	-46.333248
F5682	Alto da Serra	sp 92	*Cratera hina*	Santo André	-23.77	-46.30
Marcus, 1951	Alto da Serra	sp 92	*Cratera hina*	Santo André	-23.77591085738422	-46.32020141303849
Marcus, 1951	Cidade Jardim	sp 93	*Pasipha pasipha*	São Paulo	-23.542487525138924	-46.614574045241795
F1841	PE Alberto Löfgren	sp 93	*Pasipha pasipha*	São Paulo	-23.462758168233385	-46.63700659481653
F1842	PE Alberto Löfgren	sp 93	*Pasipha pasipha*	São Paulo	-23.462758168233385	-46.63700659481653
F1930	PE Alberto Löfgren	sp 93	*Pasipha pasipha*	São Paulo	-23.462758168233385	-46.63700659481653
F3616	PE Alberto Löfgren	sp 93	*Pasipha pasipha*	São Paulo	-23.462758168233385	-46.63700659481653
F3639	PE Alberto Löfgren	sp 93	*Pasipha pasipha*	São Paulo	-23.462758168233385	-46.63700659481653
F2871	PE Cantareira	sp 93	*Pasipha pasipha*	São Paulo	-23.460277777777776	-46.63666666666666
F0529	PETietê	sp 93	*Pasipha pasipha*	São Paulo	-23.490918	-46.516424
F0850	PETietê	sp 93	*Pasipha pasipha*	São Paulo	-23.49	-46.51
Marcus (1951)		sp 94	*"Geoplana" pavani*	Mogi das Cruzes/SP	-23.505856	-46.211903
Marcus, 1951	Freguesia do O	sp 95	*Paraba phocaica*	São Paulo	-23.494637438324354	-46.71413764072774
Marcus, 1951	Horto florestal	sp 95	*Paraba phocaica*	São Paulo	-23.45565259401509	-46.637007330822264
F3741	PE Cantareira	sp 95	*Paraba phocaica*	São Paulo	-23.451890	-46.637104
Marcus (1951)		sp 95	*Paraba phocaica*	São Paulo/SP	-23.500212	-46.702310
Marcus, 1951	Alto da Serra	sp 96	*Xerapoa trina*	Santo André	-23.77591085738422	-46.32020141303849
F1239	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.4482	-42.9834
F1272	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.4482	-42.9834
F1345	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.49659397554616	-43.00236847415091
F1353	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.49659397554616	-43.00236847415091
F1354	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.49659397554616	-43.00236847415091
F2547	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.455277777777777	-42.9975
F2620	Parnaso	sp 96	*Xerapoa trina*	Teresópolis	-22.45527777777	-42.9975
F2891	PE Cantareira	sp 96	*Xerapoa trina*	São Paulo	-23.46027777777	-46.6366666666
F2933	PE Cantareira	sp 96	*Xerapoa trina*	São Paulo	-23.42	-46.63
F1053	Pico do Jaraguá	sp 96	*Xerapoa trina*	São Paulo	-23.45794103370	-46.7668646619

Field Code nº or Reference	Local	Name of sp. in EA	Species	Municipality	Latitude (decimal)	Longitude (decimal)
F1055	Pico do Jaraguá	sp 96	*Xerapoa trina*	São Paulo	-23.45794103370	-46.7668646619
F2035	PN Bocaina	sp 96	*Xerapoa trina*	São José do Barreiro	-22.7501	-44.6208
F5203	PN Itatiaia	sp 96	*Xerapoa trina*	Resende	-22.454444444444444	-44.60777777777778
Marcus (1951)		sp 96	*Xerapoa trina*	Santo André/SP	-23.773397	-46.333248
Carbayo et al (2013)		sp 96	*Xerapoa trina*	Teresópolis/RJ	-22.38455	-42.97681
Carbayo et al (2013)		sp 96	*Xerapoa trina*	Teresópolis/RJ	-22.45528	-42.99750
Marcus, 1951		sp 97	*Choeradoplana bilix*	Angra dos Reis	-23.110628878545945	-44.507489234562556
Marcus (1951)		sp 97	*Choeradoplana bilix*	Angra dos Reis/RJ	-22.946008	-44.474647
Amaral et al (2012)		sp 98	*Obama carbayoi*	Derrubadas/RS	-27.247305	-53.893789
Amaral et al (2012)		sp 98	*Obama carbayoi*	Derrubadas/RS	-27.247305	-53.893789
Amaral et al (2012)		sp 98	*Obama carbayoi*	Derrubadas/RS	-27.247305	-53.893789
Amaral et al (2012)		sp 98	*Obama carbayoi*	Derrubadas/RS	-27.247305	-53.893789
F0012	Arredores do açude de Walter Bratz, Dez de Maio	sp 99	*Obama baptistae*	Toledo/PR	-24.6663	-53.9092
Amaral et al (2012)		sp 99	*Obama baptistae*	Santa Maria/RS	-29.722778	-53.714177

Final Considerations

The use of different approaches to analise the diversity of land planarians in the Atlantic forest has resulted, in this thesis, in a contribution to the knowledge on phylogeny, diversity and endemisms of this animal group.

A total of 12 species were taxonomically analysed under current standards, throughout the present work (Chapters 1 and 2). Six of them were new to science (*Cratera picuia*, *C. arucuia*, *Choeradoplana eudoxiae*, *Ch. claudioi*, *Ch. onae*, and *Ch. riutortae*) and the remaining six species were taxons in need of a revision due to the lack of relevant morphological information at the moment of classification. As a natural consequence of the increase in knowledge in morphological diversity, the diagnoses of the geoplanin genera *Cratera* and *Choeradoplana* were revised and amended. Based upon a phylogenetic framework, some diagnostic character states of these genera came out to be considered lost or derived within recently evolved in-groups, as shown in the first three chapters: *Ch. albonigra* lost the two glandular cushions and the laterally dilated cephalic region; *Cratera hina*, *C. picuia*, *C. crioula*, *C. joia* and *C. arucuia* do not present the widdening of the ejaculatory duct typical in the genus.

Current phylogenies of the Geoplaninae, from cladistic and molecular approaches, failed to recover the most basal nodes of the group. The Total Evidence phylogeny presented in this thesis produced the best resolved hypothesis for the phylogeny of the Geoplaninae so far (Chapter 3). The inferred evolutionary relationships of the Geoplanin genera show an overall concordance with previous phylogenies, but ours provided support for most clades (Grau, 2010; Carbayo et al., 2013, Amaral, 2017; Almeida et al., 2019; Negrete et al., 2019) and presented morphological congruence. Furthermore, numerous morphological characters which are traditionally used in the diagnoses of the genera, were revealed to be symplesiomorphic or to have suffered from homoplasy across the subfamily.

Beyond the taxonomic studies, we explored the geographical distribution of all land planarians recorded from across the Southeastern Atlantic forest as recorded in the literature and our own field data (Chapters 4-5). The distribution of a total of 371 known and undescribed species were used to identify Areas of Endemism. The results show that most species present a very restricted geographical distribution. The Endemicity Analysis and the Geographic Intrpolation of Endemism methods revealed numerous

areas of endemisms of these organisms. In general, these areas of endemisms are congruent with the few other studies conducted with the same fine-scale and the areas can be explained as a result of climatic variations in the Neotropic during the Neogene (Lago-Barcia et al., 2020). The niche models created for the Mid Pliocene, the Last Interglacial Maximum, the Last Glacial Maximum and the preset date, have shown that these endemic patterns of land planarians can be explained through processes of reduction and expansion of suitability areas formed from the Neogene to the present date. These processes of reduction and expansion of suitability areas are linked to the forest reductions occurred during these time periods.

In general, the results presented in this thesis contribute for a broader knowledge of the morhological and taxonomic richness of the geoplanin land planarians, the phyletic interrelationships among the major representatives of this group, and uncovers their biogeographical distribution into areas of endemism.

References

Almeida AL, Marques FP, Carbayo F. 2019. 'Endless forms most beautiful': taxonomic revision of the planarian Geoplana vaginuloides (Darwin, 1844) and discovery of numerous congeners (Platyhelminthes: Tricladida). *Zoological Journal of the Linnean Society* 185(1): 1-65.

Amaral S. 2017. Taxonomia e filogenia de espécies de Geoplaninae (Platyhelminthes) com ênfase nos gêneros Pasipha Ogren & Kawakatsu, 1990 e Imbira Carbayo et al., 2013. Universidade do Vale do Rio dos Sinos. (unpublished Ph.D. thesis)

Carbayo F, Álvarez-Presas M, Olivares CT, Marques FPL, Froehlich EM, Riutort M. 2013. Molecular phylogeny of Geoplaninae (Platyhelminthes) challenges current classification: proposal of taxonomic actions. *Zoologica Scripta* 42:508–528.

Grau JH. 2010. Relações filogenéticas entre os gêneros de Geoplaninae (Platyhelminthes, Tricladida) inferidas de caracteres morfológicos. Universidade de São Paulo, São Paulo, Brazil. (Unpublished Master Project).

Lago-Barcia D, DaSilva MB, Conti LA, Carbayo F. 2020. Areas of endemism of land planarians (Platyhelminthes: Tricladida) in the Southern Atlantic Forest. *PLoS ONE* 15(7): e0235949. https://doi.org/10.1371/journal.pone.0235949

Lisandro N, Amaral SV, Ribeiro GG, Gonçalves JW, Valiati VH, , Damborenea C, Brusa F, Leal-Zanchet AM. 2019. Far away, so close! Integrative taxonomy reveals a new genus and species of land flatworm (Platyhelminthes: Geoplanidae) from southern South America. *Zoological Journal of the Linnean Society* XX: 1–23.

Resumo

Na presente tesis de doutorado analizamos a taxonomia, filogenia e áreas de endemismo (AoE) de planárias terrestres (Platyhelminthes, Tricladida, Geoplaninae) que habitam o Sul da Mata Atlântica, desde o Estado de Espírito Santo, até o Estado de Rio Grande do Sul, chegando até a Argentina em direção Oeste. Describimos seis espécies novas pertencentes aos gêneros *Cratera* e *Choeradoplana*, e revisamos outras seis espécies mais pertencentes aos gêneros *Cratera, Choeradoplana, Geoplana* e *Pseudogeoplana.* Também emendamos a diagnose de dois gêneros (*Cratera* e *Choeradoplana*). Analisamos as relações evolutivas dos membros da subfamilia usando seis marcadores moleculares combinados com dados morfológicos em uma análise de Total Evidence. Esta nova abordagem gerou uma filogenia melhor resolvida dos Geoplaninae, apesar de se encontrar longe de estar completamente resolvida. Mesmo assim, alguns clados supragenericos podem ser diagnosticados por sinapomorfias morfológicas. Comfirmamos que alguns caracteres morfológicos tradicionalmente usados nas diagnoses de gêneros são simplesiomorficos ou sofreram de homoplasia através dos Geoplaninae. Também identificamos várias AoE analizando a distribuição de 371 espécies descritas e não descritas. As planárias terrestres são um táxon especioso. A maioria das espécies apresenta distribuições geográficas pequenas devido a sua baixa vagilidade. Em troca, apresentam altos níveis de endemicidade na área de estudo. Um total de 18 AoE foram identificadas. Devido a alta sensibilidade às modificações ambientais destes animais, são um importante táxon para analisar o estado de conservação das florestas e sua estabilidade no tempo. Os nossos resultados contribuem para um melhor entendimento da riqueza morfológica e taxonômica das planárias terrestres, as relações evolutivas entre os representantes do grupo e para identificar as suas distribuições endêmicas.

Keywords: Geoplanidae, terrestre, planárias, endêmicas, taxonomia, filogenia.

Abstract

In the present PhD thesis we analyze the taxonomy, phylogeny and areas of endemism (AoE) of land planarians (Platyhelminthes, Tricladida, Geoplaninae) inhabiting the Southern Atlantic forest, from the State of Espirito Santo, to the State of Rio Grande do Sul, westward ranging up to Argentina. We described six new species belonging to the genera *Cratera* and *Choeradoplana,* and revised another six species belonging to the genera *Cratera, Choeradoplana, Geoplana* and *Pseudogeoplana.* We also emended the diagnosis of two genera (*Cratera* and *Choeradoplana*). The evolutionary relationships amongst the members of the subfamily were analyzed with the use of six different molecular markers combined with morphological data in a Total Evidence analysis. This new approach generated a better resolved phylogeny of the Geoplaninae, although it is far from being fully resolved. Still, some suprageneric clades can be diagnosed by morphological synapomorphies. It is also acknowledged that some morphological characters traditionally used in the diagnoses of the genera are symplesiomorphic or suffered from homoplasy across Geoplaninae as well. We also identified several AoE analyzing planarian distributions of 371 described and undescribed species. Land planarians are a specious taxon. Most of the species present a small geographical distribution due to their low vagility. In turn, they present high levels of endemicity throughout the study area. A total of 18 AoE were identified. Due to their sensitivity to modifications in their environment they are an important taxon when analyzing the state of conservation of forests and their temporal stability. Our results contribute to a better understanding of the morphological and taxonomic richness of the land planarians, the evolutionary relationships among the representatives of the group, and to identify their endemic distributions.

Keywords: Geoplanidae, terrestrial, flatworms, endemic, taxonomy, phylogeny.