



Ecology

A study on monogenean parasites from the gills of some cichlids (Pisces: Cichlidae) from the Brazilian Amazon

Estudio sobre monogéneos parásitos en branquias de cíclidos (Pisces: Cichlidae) de la Amazonia Brasileña

Aristides Ferreira-Sobrinho^a, Marcos Tavares-Dias^{a,b,*}

^a Tropical Biodiversity Postgraduate Program (PPGBio), Federal University of Amapá, Rodovia Juscelino Kubitschek, s/n, 69903-419 Macapá, Brazil

^b Embrapa Amapá, Rodovia Juscelino Kubitschek, N° 2600, 68903-419 Macapá, Amapá State, Brazil

Received 12 June 2015; accepted 3 March 2016

Available online 12 August 2016

Abstract

The aim of this study was to investigate monogenean fauna in gills of *Geophagus camopiensis*, *Pterophyllum scalare*, *Satanoperca jurupari*, and *Satanoperca acuticeps* in a tributary from the Amazon River system in Brazil. A total of 2,148 monogenean specimens were collected from 140 fish examined from March 2012 to March 2013, and 84.3% of these fish were parasitized by 1 or more species. Such monogeneans were: *Sciadicleithrum geophagi*, *Sciadicleithrum juruparii*, *Gussevia spiralocirra* and *Gyrodactylus* sp. However, only *G. camopiensis* was parasitized by more than 1 species of monogenean, while *S. jurupari* and *S. acuticeps* were parasitized by the same species. Prevalence, mean intensity and mean abundance varied among host species and the highest levels of infection were by *G. spiralocirra* followed by *S. geophagi*, both parasites with aggregated dispersion. Abundance of monogeneans was not influenced by the size of the host. In *G. camopiensis*, the infection levels by *S. geophagi* did not vary during the rainy or drainage seasons. This is the first study on monogenean infections for *G. camopiensis* and *S. acuticeps*. All Rights Reserved © 2016 Universidad Nacional Autónoma de México, Instituto de Biología. This is an open access item distributed under the Creative Commons CC License BY-NC-ND 4.0.

Keywords: Amazon; Ectoparasites; Freshwater fish; Helminths; Monogenea

Resumen

El objetivo de este estudio fue investigar la fauna de monogéneos en las branquias de *Geophagus camopiensis*, *Pterophyllum scalare*, *Satanoperca jurupari* y *Satanoperca acuticeps* en un afluente del sistema del río Amazonas en Brasil. De marzo de 2012 a marzo del 2013 se examinaron 140 peces, en los cuales se encontraron 2,148 monogéneos, el 84.3% de los peces resultaron parasitados por una o más especies: *Sciadicleithrum geophagi*, *Gyrodactylus* sp., *Gussevia spiralocirra* y *Sciadicleithrum juruparii*. Sin embargo, solo *G. camopiensis* albergaba más de una especie de monogéneos, mientras *S. jurupari* y *S. acuticeps* resultaron infectadas por la misma especie. La prevalencia, la intensidad media y la abundancia variaron entre especies de hospedero y los niveles más altos de infección fueron causados por *G. spiralocirra*, seguido por *S. geophagi*, ambos parásitos con dispersión agregada. La abundancia de monogéneos no resultó influenciada por el tamaño del hospedero. En *G. camopiensis*, los niveles de infección por *S. geophagi* no variaron durante la estación seca o la temporada de lluvias. Este es el primer estudio de infecciones de monogéneos en *G. camopiensis* y *S. acuticeps*.

Derechos Reservados © 2016 Universidad Nacional Autónoma de México, Instituto de Biología. Este es un artículo de acceso abierto distribuido bajo los términos de la Licencia Creative Commons CC BY-NC-ND 4.0.

Palabras clave: Amazonia; Ectoparásitos; Peces de agua dulce; Helmintos; Monogenea

* Corresponding author.

E-mail address: marcos.tavares@embrapa.br (M. Tavares-Dias).

Peer Review under the responsibility of Universidad Nacional Autónoma de México.

Introduction

Monogeneans are helminth ectoparasites parasitizing mainly fish. They can fix to body surfaces, fins, swabs or nasal cavities of the hosts. However, a few species are endoparasites, inhabiting the stomach, intestine or urinary bladder of fishes. They have a direct life cycle and consequently a high reproduction rate. Thus, many ectoparasite species are pathogenic to the host, causing serious problems for fish farms (Boeger & Viana, 2006; Cohen, 2013). They are parasites with high host specificity if compared to other helminths (Bellay, Ueda, Takemoto, Lizama, & Pavanelli, 2012; Boeger & Viana, 2006; Braga, Araújo, & Boeger, 2014; Poulin, 1992), and some monogenean species may have a seasonal infection pattern (Boeger & Viana, 2006; Neves, Pereira, Tavares-Dias, & Luque, 2013; Tavares-Dias, Oliveira, Gonçalves, & Silva, 2014).

Neotropical cichlids are often parasitized by species of *Gussevia* Kohn and Paperna, 1964, *Sciadicleithrum* Kritsky, Thatcher, and Boeger, 1989, *Trinidactylus* Hanek, Molnar and Fernando, 1974, *Tucunarella* Mendoza-Franco, Scholz, and Rozkosna, 2010 (Braga et al., 2014; Melo, Santos, & Santos, 2012; Mendoza-Franco & Vidal-Martínez, 2005; Pariselle et al., 2011; Paschoal, Scholz, Tavares-Dias, & Luque, 2016). However, Brazilian cichlids have been mostly parasitized by *Gussevia* and *Sciadicleithrum* species and infection levels are highly variable (Table 1). Therefore, Dactylogyridae species are the most frequent monogeneans in these freshwater cichlids.

Studies on infections by monogeneans in populations of Amazonian wild cichlids are scarce. For species of economic importance, such as *Satanoperca jurupari* Heckel, 1840; *Satanoperca acuticeps* Heckel, 1840 and *Geophagus camopiensis* Pellegrin, 1903, as well as for fish important for food consumption of riverine populations from Amazon and for ornamental aquaculture information is limited (Soares et al., 2011). In addition, the monogenean fauna is also unknown for *Pterophyllum scalare* Schultze, 1823, a fish utilized in Amazonian aquaculture and the ornamental industry in Asia, Europe and North America (Tavares-Dias, Lemos, & Martins, 2010). However, some monogenean species have been reported in some cichlids from the Amazon Basin.

In the Amazon region, *Gussevia spiralicirra* Kritsky, Thatcher and Boeger, 1986 (Kritsky et al., 1986), and *Sciadicleithrum iphthimum* Kritsky, Thatcher and Boeger, 1989 were described from *P. scalare* (Kritsky et al., 1989). Recently, Tripathi, Agrawal, and Sriivastana (2010) found *S. iphthimum* parasitizing the gills of *P. scalare* in aquariums in India, due to intercontinental translocation of this ornamental fish from the Amazon. *Sciadicleithrum juruparii* Melo, Santos and Portes-Santos, 2012 (Melo et al., 2012), *Sciadicleithrum satanopercae* Yamada, Takemoto, Bellay and Pavanelli, 2009 (Mendoza-Franco, Scholz, & Rozkošná, 2010) and *Sciadicleithrum edgari* Paschoal, Scholz, Tavares-Dias & Luque, 2016 (Paschoal et al., 2016) were described from *S. jurupari*. Therefore, since there are no other studies on parasites of wild *P. scalare*, *S. jurupari*, *G. camopiensis* and *S. acuticeps*, this study investigated the

fauna of monogeneans of these hosts from a tributary of the Amazon River system, in Northern Brazil.

Materials and methods

The Matapi River basin, with 2,518 km², crosses the city of Porto Grande, flowing into the mouth on the Amazon River, in the municipality of Santana, Amapá State (eastern Amazon, Brazil). This watershed spreads over different cities and has several tributaries, including rivers and streams (Fig. 1), all used by various human riverine communities that earn their living from agriculture, livestock and fisheries. It is strongly influenced by a high rainfall in the Amazon region and also by the daily tides of the Amazon River (Takiyama et al., 2007).

From March 2012 to March 2013, 75 specimens of *G. camopiensis* (12.5 ± 3.1 cm and 62.0 ± 43.0 g), 38 specimens of *P. scalare* (4.5 ± 0.8 cm and 6.0 ± 4.4 g), 15 specimens of *S. jurupari* (11.8 ± 1.6 cm and 58.5 ± 10.4 g) and 12 specimens of *S. acuticeps* (11.6 ± 1.1 cm and 50.0 ± 14.5 g) were collected along the Matapi River (Fig. 1). Fish were caught with cast nets, matapi, longlines, handlines and gillnets (20, 30, 40 and 50 mm between nodes) to study monogeneans from gills.

For *G. camopiensis*, the most captured host species, 39 specimens were collected during the rainy period and 36 during the drought period aiming to study the effects of seasonality in levels of infection. Seasonality was based on rainy and dry seasons, as the region is a tropical forest characterized by a rainy season that runs from December to May (summer and fall) and a dry season that runs from June to November (autumn and winter) (Souza & Cunha, 2010).

For each fish, standard length (cm) and body weight (g) were obtained. The gills were collected and fixed in 5% formalin to collect monogeneans, which were then quantified and preserved in 70% alcohol. To analyze the internal morphology of monogeneans, GAP (picric acid and glycerin) and Hoyer methods were used to study the sclerotized structures. Some parasites were also stained with Masson trichrome (Boeger & Viana, 2006).

The ecological terms used are those recommended by Bush, Lafferty, Lotz, and Shostak (1997). The index of dispersion (ID) and index of discrepancy (D) were calculated using the Quantitative Parasitology 3.0 software to detect the distribution pattern for each infracommunity of parasites (Rózsa, Reiczigel, & Majoros, 2000) in species with a prevalence ≥ 10%. The significance of ID for each parasite species was tested using the *d*-statistics (Ludwig & Reynolds, 1988).

To study seasonality, the prevalence of parasites was compared between seasons using the Chi-square (χ^2) test, and the abundance was calculated using the Mann–Whitney (*U*) test. Spearman correlation coefficient (*r*_s) was used to determine possible correlations between abundance of parasites and length and body weight of hosts (Zar, 2010).

During fish collection, in each sampling site along the Matapi River, the pH, water temperature and dissolved oxygen were measured using the appropriate digital devices for each purpose. The mean rainfall was obtained from the Center for

Table 1
Monogenean species on native cichlids in Brazil.

Parasites	Host fish	p (%)	MI	Locality	References
<i>Gussevia asota</i>	<i>Astronotus ocellatus</i>	71.4	17.6	Guandu river (RJ)	Abdallah, Azevedo, and Luque (2008)
<i>Gussevia asota</i>	<i>Astronotus ocellatus</i>	65.7	11.2	Guandu river (RJ)	Azevedo, Abdallah, and Luque (2011)
<i>Gussevia asota</i>	<i>Astronotus crassipinnis</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia asota</i>	<i>Astronotus ocellatus</i>	–	–	Janauacá lake (AM)	Kritsky et al. (1989)
<i>Gussevia asota</i>	<i>Astronotus ocellatus</i>	100	19.5	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia astronoti</i>	<i>Astronotus ocellatus</i>	–	–	Janauacá lake (AM)	Kritsky et al. (1989)
<i>Gussevia astronoti</i>	<i>Astronotus ocellatus</i>	62.8	17.5	Guandu river (RJ)	Abdallah et al. (2008)
<i>Gussevia astronoti</i>	<i>Astronotus ocellatus</i>	71.4	7.3	Guandu river (RJ)	Azevedo et al. (2011)
<i>Gussevia astronoti</i>	<i>Astronotus crassipinnis</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia tucunarense</i>	<i>Cichla ocellaris</i>	27.0	8.0	Guandu river (RJ)	Azevedo et al. (2011)
<i>Gussevia tucunarense</i>	<i>Cichla ocellaris</i>	–	–	Negroriver (AM)	Kritsky et al. (1986)
<i>Gussevia tucunarense</i>	<i>Cichla kelberi</i>	18.4	–	Lajes reservoir (RJ)	Yamada, Santos, and Takemoto (2011)
<i>Gussevia undulata</i>	<i>Cichla ocellaris</i>	60.0	–	Guandu river (RJ)	Abdallah (2009)
<i>Gussevia undulata</i>	<i>Cichla ocellaris</i>	19.0	7.4	Guandu river (RJ)	Azevedo et al. (2011)
<i>Gussevia undulata</i>	<i>Cichla kelberi</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia undulata</i>	<i>Cichla ocellaris</i>	–	–	Rio Negro (AM)	Kritsky et al. (1986)
<i>Gussevia undulata</i>	<i>Cichla piquiti</i>	12.2	–	Paraná river (PR)	Yamada et al. (2011)
<i>Gussevia undulata</i>	<i>Cichla kelberi</i>	23.7	–	Lajes reservoir (RJ)	Yamada et al. (2011)
<i>Gussevia arilla</i>	<i>Cichla kelberi</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia arilla</i>	<i>Cichlasoma bimaculatum</i>	62.5	2.8	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia longihaptor</i>	<i>Cichla kelberi</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia longihaptor</i>	<i>Cichla ocellaris</i>	–	–	Rio Amazonas (AM)	Kritsky et al. (1986)
<i>Gussevia longihaptor</i>	<i>Cichla piquiti</i>	19.5	–	Paraná river (PR)	Yamada et al. (2011)
<i>Gussevia rogersi</i>	<i>Astronotus crassipinnis</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Gussevia rogersi</i>	<i>Astronotus ocellatus</i>	–	–	Solimões river (AM)	Kritsky et al. (1989)
<i>Gussevia obtusa</i>	<i>Uaru amphiacanthoides</i>	–	–	Negro river (AM)	Kritsky et al. (1986)
<i>Gussevia altioides</i>	<i>Cichlasoma severum</i>	–	–	Solimões river (AM)	Kritsky et al. (1986)
<i>Gussevia alioides</i>	<i>Aequides tetramerus</i>	–	–	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia disparoides</i>	<i>Cichlasoma severum</i>	–	–	Rio Solimões (AM)	Kritsky et al. (1986)
<i>Gussevia disparoides</i>	<i>Aequides tetramerus</i>	–	–	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia disparoides</i>	<i>Cichlassoma amazonarum</i>	16.7	1.8	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia disparoides</i>	<i>Chaetobranchius flavescens</i>	–	–	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia arilla</i>	<i>Cichla ocellaris</i>	–	–	Negro river (AM)	Kritsky et al. (1986)
<i>Gussevia dispar</i>	<i>Cichlasoma severum</i>	–	–	Solimões river (AM)	Kritsky et al. (1986)
<i>Gussevia elephus</i>	<i>Chaetobranchius flavescens</i>	–	–	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia spiralicirra</i>	<i>Aequidens</i> sp.	100	23.2	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia</i> sp.	<i>Astronotus ocellatus</i>	71.4	17.6	Guandu river (RJ)	Azevedo, Abdallah, and Luque (2007)
<i>Gussevia</i> sp.	<i>Astronotus crassipinnis</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Sciadicleithrum ergensi</i>	<i>Cichla ocellaris</i>	15.0	3.3	Guandu river (RJ)	Azevedo et al. (2011)
<i>Sciadicleithrum ergensi</i>	<i>Cichla ocellaris</i>	–	–	Negro river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum ergensi</i>	<i>Cichla piquiti</i>	29.3	–	Paraná river (PR)	Yamada et al. (2011)
<i>Sciadicleithrum ergensi</i>	<i>Cichla kelberi</i>	76.3	–	Lajes reservoir (RJ)	Yamada et al. (2011)
<i>Sciadicleithrum guanduensis</i>	<i>Geophagus brasiliensis</i>	10.0	11.9	Guandu river (RJ)	Carvalho, Tavares, and Luque (2010)
<i>Sciadicleithrum guanduensis</i>	<i>Geophagus brasiliensis</i>	36.0	12.1	Guandu river (RJ)	Carvalho, Tavares, and Luque (2008)
<i>Sciadicleithrum frequens</i>	<i>Geophagus brasiliensis</i>	100	68.5	Paraná river (PR)	Bellay et al. (2012)
<i>Sciadicleithrum satanopercae</i>	<i>Satanoperca pappaterra</i>	75.0	23	Paraná river (PR)	Yamada et al. (2009)
<i>Sciadicleithrum satanopercae</i>	<i>Satanoperca jurupari</i>	40.0	5.4	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Sciadicleithrum joanae</i>	<i>Crenicichla niederleini</i>	41.0	11.0	Paraná river (PR)	Yamada et al. (2009)
<i>Sciadicleithrum joanae</i>	<i>Crenicichla britskii</i>	100	–	Paraná river (PR)	Yamada et al. (2009)
<i>Sciadicleithrum joanae</i>	<i>Mesonauta acora</i>	89.4	8.7	Igarapé Fortaleza (AP)	Pantoja, Flores, and Tavares-Dias (2015)
<i>Sciadicleithrum araguariensis</i>	<i>Crenicichla labrina</i>	100	–	Araguari river (AP)	Paschoal et al. (2016)
<i>Sciadicleithrum joanae</i>	<i>Mesonauta acora</i>	85.7	25.7	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Sciadicleithrum uncinatum</i>	<i>Cichla ocellaris</i>	–	–	Negro river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum uncinatum</i>	<i>Cichla piquiti</i>	17.1	–	Paraná river (PR)	Yamada et al. (2011)
<i>Sciadicleithrum tortrix</i>	<i>Uaru amphiacanthoides</i>	–	–	Negro river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum umbilicum</i>	<i>Cichla ocellaris</i>	–	–	Negro river (AM)	Kritsky et al. (1989)

Table 1 (Continued)

Parasites	Host fish	p (%)	MI	Locality	References
<i>Sciadicleithrum iphthimum</i>	<i>Pterophyllum scalare</i>	–	–	Solimões river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum iphthimum</i>	<i>Pterophyllum scalare</i>	100	13.4	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Gussevia spiralicirra</i>	<i>Pterophyllum scalare</i>	92.8	32.8	Igarapé Fortaleza (AP)	Pantoja et al. (2015)
<i>Sciadicleithrum geophagi</i>	<i>Geophagus surinamensis</i>	–	–	Negro river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum geophagi</i>	<i>Chaetobranchopsis orbicularis</i>	58.1	12.8	Igarapé Fortaleza (AP)	Bittencourt et al. (2014)
<i>Sciadicleithrum variabilellum</i>	<i>Symphysodon discus</i>	–	–	Amazon river (AM)	Kritsky et al. (1989)
<i>Sciadicleithrum aequidens</i>	<i>Aequidens maroni</i>	–	–	Guiana Inglesa	Kritsky et al. (1989)
<i>Sciadicleithrum juruparii</i>	<i>Satanoperca jurupari</i>	–	–	Guamá river (PA)	Melo et al. (2012)
<i>Sciadicleithrum edgari</i>	<i>Satanoperca jurupari</i>	50.0	–	Araguari river (AP)	Paschoal et al. (2016)
<i>Sciadicleithrum cavanaughi</i>	<i>Aequidens maroni</i>	–	–	Guiana Inglesa	Kritsky et al. (1989)
<i>Sciadicleithrum</i> sp.	<i>Crenicichla niederleini</i>	41.5	11.0	Paraná river (PR)	Yamada et al. (2008)
<i>Sciadicleithrum</i> sp.	<i>Crenicichla niederleini</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Sciadicleithrum</i> sp.	<i>Satanoperca pappaterra</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Sciadicleithrum</i> sp.	<i>Satanoperca pappaterra</i>	64.7	23.0	Paraná river (PR)	Yamada et al. (2008)
<i>Sciadicleithrum</i> sp.	<i>Crenicichla britskii</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Sciadicleithrum</i> spp.	<i>Geophagus brasiliensis</i>	40.9	20.3	Parque Ingá lake (PR)	Graça and Machado (2007)
<i>Sciadicleithrum</i> spp.	<i>Geophagus proximus</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Cleidodiscus</i> sp.	<i>Satanoperca pappaterra</i>	–	–	Paraná river (PR)	Takemoto et al. (2009)
<i>Cleidodiscus</i> sp.	<i>Laetacara</i> sp.	–	–	Paraná river (PR)	Takemoto et al. (2009)

P, prevalence; MI, mean intensity.

Hydrometeorology and Renewable Energy (NHMET) of the Institute of Scientific and Technological Research of Amapá State (IEPA).

Results

From a total of 140 fish, 84.3% were parasitized by *Sciadicleithrum geophagi* Kritsky et al., 1989, *Gussevia spiralicirra* Kohn & Paperna 1964, *S. juruparii* and/or *Gyrodactylus* sp., and 2,148 parasites were collected. *Satanoperca jurupari* was the host with the lowest level of infection, and only *G. camopiensis* was parasitized by more than 1 parasite species. *Gussevia spiralicirra* was the monogenean species with the highest level of infection, followed by *S. geophagi* and *S. juruparii*, which infected more than 1 host (Table 2).

During the rainy season, the mean water temperature was 28.4 ± 0.9 °C, pH 5.7 ± 0.5 , dissolved oxygen 5.4 ± 2.7 mg/L and mean rainfall 357.2 ± 88.5 mm. In the dry season, the mean water temperature was 28.4 ± 1.1 °C, pH 5.5 ± 0.07 , dissolved oxygen 3.5 ± 1.6 mg/L and mean rainfall 43.4 ± 47.8 mm.

In *G. camopiensis*, the prevalence of *S. geophagi* was 87% in the rainy season and 89% during the dry season, thus indicating no seasonal differences ($\chi^2 = 0.052$, $p = 0.820$). The mean abundance of *S. geophagi* in the rainy season was 5.4 and 5.7 in the dry season; therefore, there were no differences ($U = 652.0$, $p = 0.595$) between these 2 seasons.

The helminths *S. geophagi* and *G. spiralicirra*, showed an aggregated dispersion pattern (Table 3). No significant correlation between the abundance of monogenean species and length and weight of hosts was found (Table 4).

Discussion

Thirty-one monogenean species for native cichlids from South America are listed, and 80.6% of these parasites are known to infect cichlids from Brazil (Cohen, Just, & Kohn,

2013). In wild populations of *G. camopiensis*, *P. scalare*, *S. acuticeps* and *S. jurupari*, the monogenean fauna was composed by *S. geophagi*, *S. juruparii*, *G. spiralicirra*, and *Gyrodactylus* sp., parasite species known to parasitize cichlid species. Only *G. camopiensis* was parasitized by more than 1 monogenean, *S. geophagi* and *Gyrodactylus* sp. Although, *S. acuticeps* and *S. jurupari*, are probably phylogenetically close hosts, were parasitized by *S. juruparii*. The richness of monogeneans may vary among different cichlids, since some ancirocephalid species of South America and Africa have a low host specificity, infecting different hosts (Pariselle et al., 2011), while others infect only a few host species (Boeger & Viana, 2006; Braga et al., 2014; Cohen et al., 2013), as occurred in the present study. Nevertheless, monogeneans seem to infect potentially available hosts when both have experienced a co-evolution (Braga et al., 2014; Poulin, 1992).

The monogenean *S. iphthimum*, from the gills of *P. scalare* of central Amazon, was not found in this host in the present study. Anyhow, *S. geophagi*, described from gills of *Geophagus surinamensis* Bloch, 1791 from Solimões River (Table 1), was found to parasitize *G. camopiensis* for the first time. It was also found that only 1 individual of *G. camopiensis* had 6 specimens of *Gyrodactylus* von Nordmann, 1932, thereby precluding identification of the species. In South America, few species of *Gyrodactylus* are known to parasitize cichlid species. *Gyrodactylus cichlidarum* Paperna, 1968 has been reported in *Oreocromis niloticus* Linnaeus, 1758 from Colombia and Ecuador (García-Vásquez et al., 2010), and *Gyrodactylus geophagensis* Boeger & Popazoglo, 1995 in *G. brasiliensis* from Brazil (Cohen et al., 2013). However, the *Gyrodactylus* specimens found in *G. camopiensis* present no resemblance to *G. geophagensis*. This is the first report of the monogenean *S. juruparii* in *S. acuticeps*.

The lentic environment, preferred by *G. camopiensis*, *P. scalare*, *S. acuticeps* and *S. jurupari*, favors dispersal and reproduction of monogeneans, ectoparasites with free-living stages during some phases of its lifecycle (Bittencourt, Pinheiro,

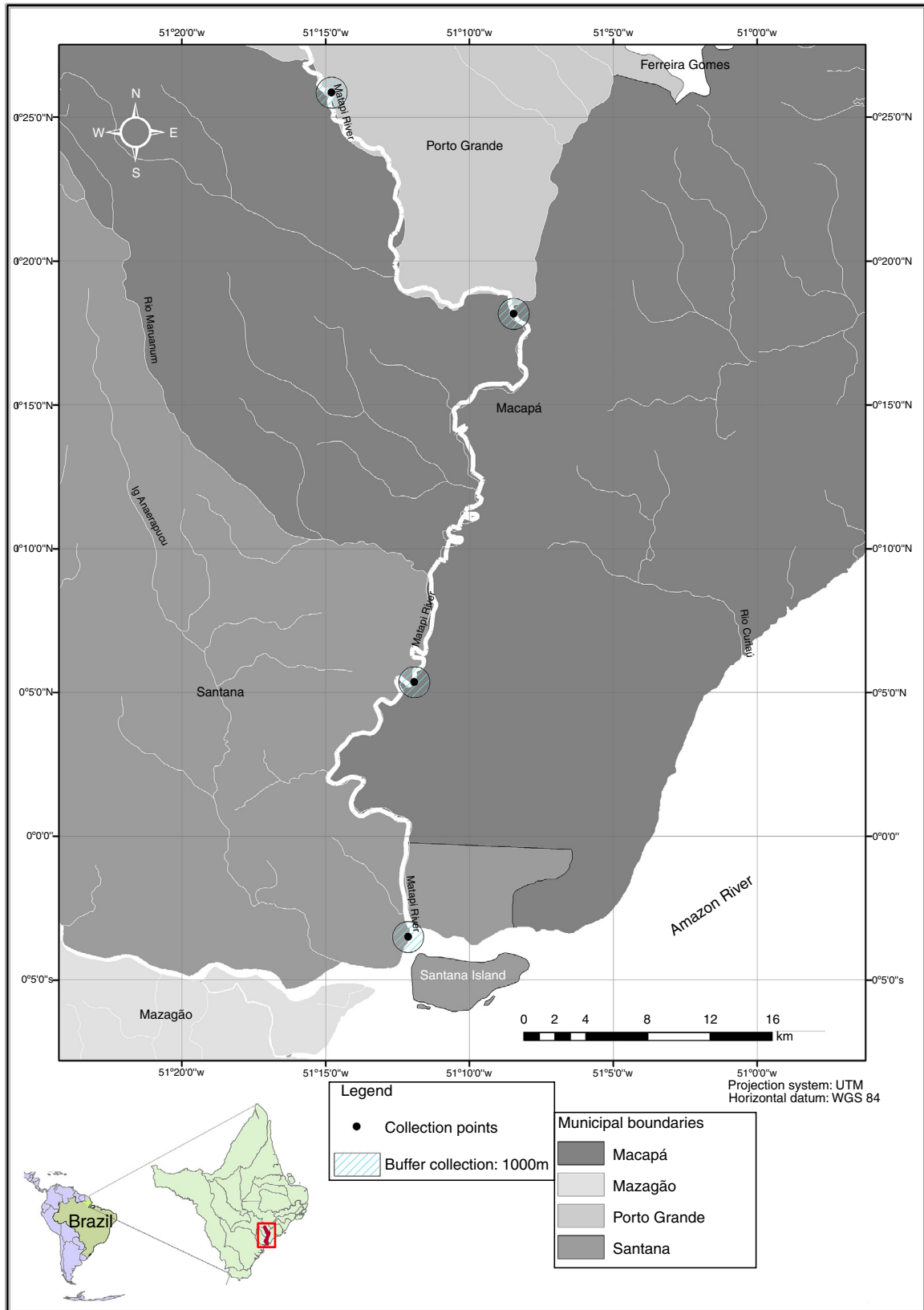


Figure 1. Geographic location of the study area and sampling sites along the Matapi River, eastern Amazon, Brazil.

Table 2
Infection by monogeneans in the gills of cichlid species from eastern Amazon, Brazil.

Host fish	Parasite species	EF	P (%)	MI	MA	TNP
<i>Geophagus camopiensis</i>	<i>Sciadicleithrum geophagi</i>	75	88	6.3	5.5	416
	<i>Gyrodactylus</i> sp.	–	1	6.0	0.08	6
<i>Pterophyllum scalare</i>	<i>Gussevia spiralicirra</i>	38	100	39.3	39.3	1492
<i>Satanoperca acuticeps</i>	<i>Sciadicleithrum juruparii</i>	12	67	25.3	16.8	202
<i>Satanoperca jurupari</i>	<i>Sciadicleithrum juruparii</i>	15	40	5.3	2.1	32

EF, examined fish; P, prevalence; MI, mean intensity; MA, mean abundance; TNP, total number of parasites.

Table 3
Dispersion index (DI), index of discrepancy (D) and *d*-statistic for infracommunities of monogeneans in cichlid species of the eastern Amazon, Brazil.

Host fish	Parasite species	DI	<i>d</i>	D
<i>Geophagus camopiensis</i>	<i>Sciadicleithrum geophagi</i>	2.542	7.3	0.43
<i>Pterophyllum scalare</i>	<i>Gussevia spiralicirra</i>	1.577	2.3	0.31

Cárdenas, Fernandes, & Tavares-Dias, 2014; Dogiel, 1961; Neves et al., 2013). *Pterophyllum scalare* and *S. acuticeps* were the hosts with the highest level of infection when compared to *G. camopiensis* and *S. jurupari*. However, a low number of *S. acuticeps* and *S. jurupari*, were examined over an annual cycle, due to low population densities. Nevertheless, the prevalence of *S. juruparii* in these 2 hosts does not seem to be underestimated. Marques and Cabral (2007) reported that, for helminths with an aggregated dispersion pattern, as in the present study, the mean intensity and mean abundance may be under or overestimated when a small sample of host fish are examined, while prevalence is not affected. In the gills of *S. jurupari*, the intensity of *S. juruparii* ranged from 1 to 12 parasites per host, but in *S. acuticeps* it ranged from 3 to 152, demonstrating a pattern of differentiated infection. However, a lower intensity of *S. juruparii* in the gills of *S. jurupari* from Guamá River, Brazil (Table 1) was reported. *Sciadicleithrum satanopercae* also parasitized the gills of *S. jurupari* farmed in the Peruvian Amazon (Mendoza-Franco et al., 2010), but infection levels were not studied. Therefore, these results suggest that *S. jurupari* is host to both species of monogeneans depending on their geographic location.

Table 4
Spearman correlation coefficient (*r_s*) between the abundance of monogenean species and the length and weight of cichlid species of the eastern Amazon, Brazil.

Host fish	Parasites	Length		Weight	
		<i>r_s</i>	<i>p</i>	<i>r_s</i>	<i>p</i>
<i>Geophagus camopiensis</i>	<i>S. geophagi</i>	0.019	0.870	0.012	0.919
<i>Pterophyllum scalare</i>	<i>G. spiralicirra</i>	–0.084	0.618	–0.089	0.597
<i>Satanoperca jurupari</i>	<i>S. juruparii</i>	0.148	0.598	0.022	0.937
<i>Satanoperca acuticeps</i>	<i>S. juruparii</i>	0.115	0.649	0.085	0.736

p, probability.

In *G. camopiensis* infection levels by *S. geophagi* are higher than in *Chaetobranchopsis orbicularis* Steindachner, 1875 (Table 1), and were not influenced by seasonality due to the low environmental variation during the rainy and dry seasons. In contrast, due to seasonal environmental changes that occurred during the Amazon dry season, high levels of infection by *Gussevia asota* Kritsky et al., 1989, *Gussevia astronoti* Kritsky et al., 1989 and *Gussevia rogersi* Kritsky et al., 1989 in *Astronotus ocellatus* Agassiz in Spix and Agassiz, 1831 (Neves et al., 2013), and *Gussevia alioides* Kritsky, Thatcher & Boeger, 1986 and *Gussevia disparoides* Kritsky, Thatcher & Boeger, 1986 in *Aequidens tetramerus* Heckel, 1840 (Tavares-Dias et al., 2014) were reported. An aggregated dispersion for *S. geophagi* and *G. spiralicirra* was observed, a distribution pattern also reported for other species of dactylogirids from the gills of *A. ocellatus* (Neves et al., 2013) and *A. tetramerus* (Tavares-Dias et al., 2014), both cichlids from the Amazon. This aggregated pattern is common in fish and it can be related to the reproductive strategy of monogeneans (Scott, 1987), as well as to differences in susceptibility to infection caused by the genetic and immunological heterogeneity of hosts and environmental characteristics.

In the gills of *G. camopiensis*, *P. scalare*, *S. acuticeps* and *S. jurupari*, the high abundance of monogeneans was not influenced by host size. For *S. acuticeps* and *S. jurupari*, this lack of correlation was due to sampling of hosts with a reduced size variation. Furthermore, most specimens of *G. camopiensis* (5.3–17.5 cm) examined were adults with a low abundance of parasites. However, the abundance of *Sciadicleithrum frequens* Bellay, Takemoto, Yamada & Pavanelli, 2008 was positively correlated with the length of hosts in *Geophagus brasiliensis* Quoy & Gaimard, 1824, reflecting an accumulation of these parasites throughout fish growth (Bellay et al., 2012). On the other hand, the abundance of *G. alioides* and *G. disparoides* was negatively correlated with the length of *A. tetramerus* (Tavares-Dias et al., 2014). Therefore, different infracommunities of monogeneans may have different responses to host size, thus determining different levels of infection.

In summary, this is the first report on infection levels by monogeneans in wild populations of *S. geophagi*. For *G. camopiensis* and *S. juruparii* in *S. acuticeps* we found that parasitism was not influenced by host size. In *G. camopiensis*, the infection of *S. geophagi* also had a constant annual pattern, indicating that in these Amazonian hosts, other factors are involved in the parasitism levels of monogenean species. *S. juruparii* was found in 2 congeneric hosts and most likely may infect other *Satanoperca* species, but this needs to be further researched.

Acknowledgements

The present work was conducted according to the principles adopted by the Brazilian College of Animal Experiments (COBEA) and under the authorization from ICMBio (# 23276-1). M. Tavares-Dias was supported by a Research fellowship from Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico (CNPq, Brazil).

References

- Abdallah, V. D. (2009). *Biodiversidade dos monogenéticos (Platyhelminthes: Monogenea) parasitos de peixes do Rio Guandu, Estado do Rio de Janeiro, Brasil*. Tesis. Rio de Janeiro: Seropédica, Universidade Federal Rural do Rio de Janeiro.
- Abdallah, V. D., Azevedo, R. K., & Luque, J. L. (2008). Notes on the morphology of two species of *Gussevía* Kohn & Paperna (Monogenea: Dactylogyridae) parasitic on *Astronotus ocellatus* (Agassiz) (Perciformes: Cichlidae) from Brasil. *Pan-American Journal of Aquatic Sciences*, 3, 101–104.
- Azevedo, R. K., Abdallah, V. D., & Luque, J. L. (2007). Ecologia da comunidade de metazoários parasitos do apaiari *Astronotus ocellatus* (Cope, 1872) (Perciformes: Cichlidae) do Rio Guandu, Estado do Rio de Janeiro, Brasil. *Revista Brasileira de Parasitologia Veterinária*, 16, 15–20.
- Azevedo, R. K., Abdallah, V. D., & Luque, J. L. (2011). Biodiversity of fish parasites from Guandu River, Southeastern Brazil: an ecological approach. *Neotropical Helminthology*, 5, 185–199.
- Bellay, S., Ueda, B. H., Takemoto, R. M., Lizama, M. L. A. P., & Pavanelli, G. C. (2012). Fauna parasitária de *Geophagus brasiliensis* (Perciformes: Cichlidae) em reservatórios do Estado do Paraná, Brasil. *Revista Brasileira de Biociências*, 10, 74–78.
- Bittencourt, L. S., Pinheiro, D. A., Cárdenas, M. Q. B., Fernandes, M. B. M., & Tavares-Dias, M. (2014). Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* (Linnaeus, 1758) in tributary of Amazonas River (Brazil). *Brazilian Journal of Veterinary Parasitology*, 23, 44–54.
- Boeger, W. A., & Viana, R. T. (2006). Monogeneoidea. In V. E. Thatcher (Ed.), *Amazon fish parasites* (pp. 42–116). Sofia, Moscow: Pensoft Publishers.
- Braga, M. P., Araújo, S. B. L., & Boeger, W. A. (2014). Patterns of interaction between Neotropical freshwater fishes and their gill Monogeneoidea (Platyhelminthes). *Parasitology Research*, 113, 481–490.
- Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, W. (1997). Parasitology meets ecology on its own terms: Margolis et al., revisited. *Journal of Parasitology*, 83, 575–583.
- Carvalho, A. R., Tavares, L. E. R., & Luque, J. L. (2008). A new species of *Sciadicleithrum* (Monogenea, Dactylogyridae) parasitic on *Geophagus brasiliensis* (Perciformes, Cichlidae) from Guandu River, Southeastern Brazil. *Acta Parasitologica*, 53, 237–239.
- Carvalho, A. R., Tavares, L. E. R., & Luque, J. L. (2010). Variação sazonal dos metazoários parasitos de *Geophagus brasiliensis* (Perciformes: Cichlidae) no Rio Guandu, Estado do Rio de Janeiro, Brasil. *Acta Scientiarum Biological Sciences*, 32, 159–167.
- Cohen, S. C. (2013). On diversity of the monogeneoidean fauna in a megadiverse country, Brazil. *Neotropical Helminthology*, 7, 1–6.
- Cohen, S. C., Just, M. C. N., & Kohn, A. (2013). *South American Monogeneoidea parasites of fishes, amphibians and reptiles*. Rio de Janeiro: Oficina de Livros.
- Dogiel, V. A. (1961). Ecology of the parasites of freshwater fishes. In V. A. Dogiel, G. K. Petrushevsky, & Y. I. Polyanski (Eds.), *Parasitology of fishes* (pp. 1–47). Leningrad: University Press.
- García-Vásquez, A., Hansen, H., Christison, K. W., Rubio-Godoy, M., Bron, J. E., & Shinn, A. P. (2010). Gyrodactylids (Gyrodactylidae, Monogenea) infecting *Oreochromis niloticus niloticus* (L.) and *O. mossambicus* (Peters) (Cichlidae): a pan-global survey. *Acta Parasitologica*, 55, 215–229.
- Grça, R. J., & Machado, M. H. (2007). Ocorrência e aspectos ecológicos de metazoários parasitos de peixes do Lago do Parque do Ingá, Maringá, Estado do Paraná. *Acta Scientiarum Biological Sciences*, 29, 321–326.
- Kritsky, D. C., Thatcher, V. E., & Boeger, W. A. (1986). Revision of *Urocleidoides* (Dactylogyridae, Ancyrocephalinae). *Proceedings of the Helminthological Society of Washington*, 53, 1–37.
- Kritsky, D. C., Thatcher, V. E., & Boeger, W. A. (1989). Neotropical Monogenea. 15. Dactylogyrids from the gills of Brazilian Cichlidae with proposal of *Sciadicleithrum* gen. n. (Dactylogyridae). *Proceedings of the Helminthological Society of Washington*, 56, 128–140.
- Ludwig, J. A., & Reynolds, J. F. (1988). *Statistical ecology: a primer on methods and computing*. New York: Wiley-Interscience Publications.
- Marques, S. J. F., & Cabral, H. N. (2007). Effects of sample size on fish parasite prevalence, mean abundance and mean intensity estimates. *Journal of Applied Ichthyology*, 23, 158–162.
- Melo, M. F. C., Santos, J. N., & Santos, C. P. (2012). *Sciadicleithrum juruparii* n. sp. (Monogenea: Ancyrocephalidae) from the gills of *Satanoperca jurupari* (Heckel) (Osteichthyes: Cichlidae) in the Guamá River, Amazon Delta, Brazil. *Systematic Parasitology*, 82, 125–129.
- Mendoza-Franco, E. F., Scholz, T., & Rozkošná, P. (2010). *Tucunarella* n. gen. and other dactylogyrids (Monogeneoidea) from cichlid fish (Perciformes) from Peruvian Amazonia. *Journal of Parasitology*, 96, 491–498.
- Mendoza-Franco, E. F., & Vidal-Martínez, V. M. (2005). Phylogeny of species of *Sciadicleithrum* (Monogeneoidea: Ancyrocephalinae), and their historical biogeography in the Neotropics. *Journal of Parasitology*, 91, 253–259.
- Neves, L. R., Pereira, F. B., Tavares-Dias, M., & Luque, J. L. (2013). Seasonal influence on the parasite fauna of a wild population of *Astronotus ocellatus* (Perciformes: Cichlidae) from the Brazilian Amazon. *Journal of Parasitology*, 99, 718–721.
- Pantoja, W. M. F., Flores, L. V., & Tavares-Dias, M. (2015). Parasites component community in wild population of *Pterophyllum scalare* Schultze, 1823 and *Mesonauta acora* Castelnau, 1855, cichlids from the Brazilian Amazon. *Journal of Applied Ichthyology*, 31, 1043–1048.
- Pariselle, A., Boeger, W. A., Snoeks, J., Billon Bilong, C. F., Morand, S., & Vanhove, M. P. M. (2011). The monogenean parasite fauna of cichlids: a potential tool for host biogeography. *International Journal of Evolutionary Biology*, 1–15. <http://dx.doi.org/10.4061/2011/471480>
- Paschoal, F., Scholz, T., Tavares-Dias, M., & Luque, J. L. (2016). Dactylogyrids (Monogenea) parasitic on cichlids from northern Brazil, with description of two new species of *Sciadicleithrum* and new host and geographical records. *Acta Parasitologica*, 61, 158–164.
- Poulin, R. (1992). Determinants of host-specificity in parasites of freshwater fishes. *International Journal for Parasitology*, 22, 53–758.
- Rózsa, L. J., Reiczigel, J., & Majoros, G. (2000). Quantifying parasites in samples of hosts. *Journal of Parasitology*, 86, 228–232.
- Scott, M. E. (1987). Temporal changes in aggregation: a laboratory study. *Parasitology*, 94, 583–595.
- Soares, M. G. M., Costa, E. L., Siqueira-Souza, F. K., Anjos, H. D. B., Yamamoto, K. C., & Freitas, C. E. C. (2011). *Peixes de lagos do médio Rio Solimões* (2nd ed.). Revisada, Manaus: Instituto Piatam.
- Souza, E. B., & Cunha, A. C. (2010). Climatologia de precipitação no estado do Amapá e mecanismos climáticos de grande escala. In A. C. Cunha, A. E. B. Souza, & H. F. A. Cunha (Eds.), *Tempo, clima e recursos hídricos: resultados do projeto REMETAP no Estado do Amapá* (pp. 177–195). Macapá: IEPA.
- Takiyama, L. R., Cunha, A. C., Silva, M. S., Martins, M. H. A., Rodrigues, L. J. C., Avelar, S. B., et al. (2007). *Subsídios à gestão de recursos hídricos na bacia hidrográfica do Rio Matapi. Relatório técnico final CNPq*. Macapá: IEPA/GERCO.
- Takemoto, R. M., Pavanelli, G. C., Lizama, M. A. P., Lacerda, A. C. F., Yamada, F. H., & Moreira, L. H. A. (2009). Diversity of parasites of fish from the upper Paraná River floodplain, Brazil. *Brazilian Journal of Biology*, 69, 691–705.
- Tavares-Dias, M., Lemos, J. R. G., & Martins, M. L. (2010). Parasitic fauna of eight species of ornamental freshwater fish species from the middle Negro River in the Brazilian Amazon Region. *Revista Brasileira de Parasitologia Veterinária*, 19, 103–107.
- Tavares-Dias, M., Oliveira, M. S. B., Gonçalves, R. A., & Silva, L. M. A. (2014). Ecology and seasonal variation of parasites in wild *Aequidens tetramerus*, a Cichlidae from the Amazon. *Acta Parasitologica*, 59, 158–164.

- Tripathi, A., Agrawal, N., & Sriivastana, N. (2010). Monogenoidea on exotic Indian freshwater fishes. 1. A new geographical record of *Sciadicleithrum iphthimum* Kritsky, Tatcher, and Boeger, 1989 (Dactylogyridae) with the first description of its egg. *Comparative Parasitology*, 77, 83–86.
- Yamada, F. H., Takemoto, R. M., & Pavanelli, G. C. (2008). Relação entre fator de condição relativo (Kn) e abundância de ectoparasitos de brânquias, em duas espécies de ciclídeos da bacia do Rio Paraná, Brasil. *Acta Scientiarum Biological Sciences*, 30, 213–217.
- Yamada, F. H., Takemoto, R. M., Bellay, S., & Pavanelli, G. C. (2009). Two new species of *Sciadicleithrum* (Monogenea, Dactylogyridae) parasites of Neotropical cichlid fishes from the Paraná River, Brazil. *Acta Parasitologica*, 54, 6–11.
- Yamada, F. H., Santos, L. N., & Takemoto, R. M. (2011). Gill ectoparasite assemblages of two non-native *Cichla* populations (Perciformes, Cichlidae) in Brazilian reservoirs. *Journal of Helminthology*, 85, 185–191.
- Zar, J. H. (2010). *Biostatistical analysis*. New Jersey: Prentice Hall.