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# Qualitative and quantitative study of parasites of *Pimelodus maculatus* and *Rhamdia quelen* from the Jacaré-Pepira River, state of São Paulo, Brazil

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**Abstract:** In the freshwater ecosystems of Brazil can be found high biodiversity of fish, about 5160 species. However, the Jacaré-Pepira River, located in the state of São Paulo, Brazil, presents a diversity of fish still to be explored in ichthyological studies. Metazoan parasites of *Pimelodus maculatus* and *Rhamdia quelen* were qualitatively and quantitatively diagnosed. Ten species of parasites (*Demidospermus* sp., *D. majusculus*, *D. bidiverticulatum*, *D. paravalenciennesi*, *Ameloblastella paranaensis*, *Scleroductus* sp., *Riggia* sp., *Austrodiplostomum compactum, Helobdella* sp. and *Neochinorhynchus pimelodi*) were collected in *P. maculatus* and eight species of parasites (*Aphanoblastella robustus*, *A. mastigatus*, *Phyllodistomum rhamdiae*, *Crocodilicola pseudostoma*, *Henneguya jundiai*, *Contracaecum* sp., *Rhabdochona* sp. and Capillariidae gen. sp.) were collected in *R. quelen*. All parasites presented aggregate distribution. A significant correlation was observed in *P. maculatus* concerning the weight with the prevalence of ectoparasite *D. majusculus*; however, *R. quelen* showed a relation to the length and weight with the abundance of ectoparasite *A. mastigatus* and endoparasites. The parasitic community of *P. maculatus* and *R. quelen* was characterized by high diversity, high richness, and low uniformity.

**Key words:** biodiversity, ecology, fish, freshwater, Siluriformes.

## INTRODUCTION

The Tietê/Jacaré Hydrographic Basin is located in the center of the state of São Paulo and comprises three main rivers: Tietê, Jacaré-Guaçu, and Jacaré-Pepira. The Jacaré-Pepira River, a study area, known as "Pantaninho", rises on the border between the cities of Brotas and São Pedro and flows into the Tietê River, in the city of Ibitinga, being considered one of the cleanest rivers in the state of São Paulo (Comitê da Bacia Hidrográfica do Rio Jacaré-Pepira 2015).

Brazil is among the countries that have megadiversity, with a considerable amount of species of animals and vegetables, especially in the freshwater and marine environments (Canhos et al. 2015, Reis et al. 2016). In freshwater ecosystems, high biodiversity of fish can be found, about 5160 species (Reis et al. 2016).

The siluriform *Pimelodus maculatus* Lacepède 1803 is commonly known as "mandi", "mandi-amarelo" or "bagre pintado", has geographical distribution restricted to South America, is characterized as opportunistic species, is active at night, and has an omnivorous feeding habit, and adaptation to a varied diet, consuming seaweed, insects, crustaceans or mollusks (Brasil-Sato & Pavanelli 2004,

Bachmann et al. 2007, Albuquerque et al. 2008, Froese & Pauly 2018) and the siluriform *Rhamdia quelen* Quoy & Gaimard 1824 is commonly known as "Jundiá", is distributed in Central and South America, as well as in southern Brazil, has benthonic behavior and nocturnal and omnivorous habit with a carnivorous tendency, thus consuming fish, crustaceans, insects, plants or mollusks (Morais 2005, Vianna et al. 2005, Froese & Pauly 2018).

Parasitism is vital in ecosystems because it regulates the abundance and density of host populations, stabilizing food chains, and structuring animal communities (Luque & Poulin 2007). Therefore, it is essential to carry out studies to determine parasitic diversity and consequently contribute to global biodiversity; thus, the objective of this study was to analyze the parasitic fauna of *P. maculatus* and *R. quelen* from the Jacaré-Pepira River, checking the quantitative data, diversity and possible influences of host length, weight, and sex on parasitism.

## MATERIALS AND METHODS

A total of 62 fish specimens were collected in the Jacaré-Pepira River (21°53'30.8"S 48°48'46.0"W) in the city of Ibitinga, state of São Paulo, Brazil. Thirty-two specimens of *P. maculatus* were collected between March and September 2016 and 30 samples of *R. quelen* were collected between January and May 2017 with a simple mesh fishing net under the authorization to capture (SISBio, number 55914-1) and Ethics Committee on the Use of Animals (CEUA, number 9530230816). At the time of collection, the fish were placed in individual plastic bags to avoid changes in their parasitic fauna or loss of materials. The fish were transported in a refrigerated thermal box until they arrived at the laboratory, where they were refrigerated in a freezer until necropsy. At the time of autopsy, information on the collection date, weight (g), standard length (cm), and host sex were recorded.

The parasites were collected and processed according to the procedures indicated by Eiras et al. (2006). The organs were removed individually, the surface of the body, mouth, nostril, and gills were washed with a 53 µm sieve for the collection of ectoparasites. Afterward, the eyes and organs of the visceral cavity were washed with a 75 µm sieve for the collection of endoparasites. Then, the organs were placed in Petri dishes and observed in a stereomicroscope. The collected parasites were fixed in 70°GL ethanol until the time of staining and/or clarification procedures and were mounted between the microscope slide and coverslip.

For identification, the monogeneans were mounted on Grey & Wess to visualize sclerotized structures, the nematodes were mounted in Amann's Lactophenol, the Isopoda was clarified with lactic acid, and other parasites (Digenea, Acanthocephala, and Hirudinea) were stained with Mayer's Carmalum (Eiras et al. 2006). Digenea were cleared using Eugenol and Acanthocephala and Hirudinea using Beechwood Creosote. The slides were mounted in Canada Balsam and analyzed with the aid of a microscope (Nikon Eclipse E200). After the visualization in the microscope, the species were identified from specific literature for each parasite group. Metacercariae were stained to perform morphological and morphometric analysis, some specimens were also fixed in absolute ethanol to be submitted to molecular biology procedure. For the identification of myxozoan, the cysts still fresh were ruptured between slide and coverslip, and other cysts were fixed in absolute ethanol to perform the molecular biology.

According to Bush et al. (1997), the quantitative analyzes, such as the prevalence, mean intensity, and mean abundance of each component of the parasite communities were calculated. As also, following the methodology of Rohde et al. (1995), the frequency of dominance of each parasite species was determined by the number of times a parasite species was dominant in all hosts analyzed.

The community status of the parasites was determined according to Caswell (1978) and Hanski (1982), cited by Bush & Holmes (1986) related to the result of the prevalence of parasite species, therefore, central species are those that are parasitizing more than 66% of their hosts, secondary species are those that are parasitizing between 33% and 66% of their hosts and satellites species are those that are parasitizing less than 33% of their hosts.

The dispersion index (ID) was calculated to indicate the level of aggregation and the type of distribution of parasitic infrapopulation, however, when ID > 1: aggregate distribution, ID = 1: random distribution, and ID < 1: uniform distribution. The statistical test *d* was calculated to evaluate the significance of the index, however, when $d \geq 1.96$ = aggregate distribution, $d \leq 1.96$ = random distribution, and $d \leq -1.96$ = uniform distribution (Ludwig & Reynolds 1988).

The following correlations were made by the PAST 3.16 software. Pearson correlation coefficient (*r*) was performed to determine the possible relationships between parasite abundance with length and weight of the hosts and Spearman correlation coefficient (*rs*) was performed to determine the possible correlations between parasite prevalence with length and weight of the hosts (Zar 1999).

The ANOVA, Tukey significance, and Kruskal-Wallis tests were applied to analyze the effect of host sex (male, female and immature, due to the time of the fish that could not be verified sex) on total parasite abundance and the Dunn's Post-Hoc test was applied to analyze the effect of host sex (male, female and immature) on the parasite abundance of ectoparasites and endoparasites.

The parasitic diversity was determined for each infracommunity by the Brillouin index (H), richness was determined by the Margalef index (*d*), equitability was determined by the Pielou uniformity index (J), and dominance was calculated by the Berger-Parker index (d) (Zar 1999).

All tests mentioned were applied only for the parasite species with prevalence more significant than 10%. The results of the statistical analyzes were considered significant when $p < 0.05$.

## RESULTS

*Pimelodus maculatus* specimens (length of 24.90 ± 2.10 cm and weight of 407.84 ± 77.28 g) and *R. quelen* specimens (length of 14.93 ± 4.69 cm and weight of 63.05 ± 76.29 g) had previous averages. The weight of *R. quelen* had a standard deviation more significant than the average, due to the intense variation between the fish weight.

Ninety percent of *P. maculatus* specimens and only 26% of *R. quelen* specimens had at least one species of metazoan parasite. A total of 1796 and 285 parasites were collected from *P. maculatus* and *R. quelen*, respectively. In *R. quelen*, 11 cysts with myxozoan spores were also collected.

In the *P. maculatus* specimens, the following groups of metazoan parasites were found: Monogenea, Acanthocephala, Hirudinea, Isopoda, and Digenea. Of these, the monogeneans (n = 1467) presented higher numbers of specimens about the abundance of the other groups of parasites. Six species of Monogenea were

identified: *Demidospermus majusculus* Kritsky & Gutiérrez 1998, *D. bidiverticulatum* Suriano & Incorvaia 1995, *D. paravalenciennesi* Gutiérrez & Suriano 1992, *Demidospermus* sp. Suriano 1983, *Ameloblastella paranaensis* França, Isaac, Pavanelli & Takemoto 2003, *Scleroductus* sp. Jara & Cone 1989 parasitizing the gills and surface of hosts. A single specimen of isopod, *Riggia* sp. Szidat 1948, measuring 1.75 x 0.64 mm, was found on the surface. A species belonging to subclass Digenea was collected as a metacercaria parasitizing the eyes and identified as *Austrodiplostomum compactum* Lutz 1928. Hirudinean of the genus *Helobdella* Blanchard 1896 were found parasitizing the surface, gills, and mouth. Also, in these fish were found acanthocephalans *Neochinorhynchus pimelodi* Brasil-Sato & Pavanelli 1998 parasitizing the intestine and stomach of the hosts. In the *R. quelen* specimens, the following groups of metazoan parasites were found: Monogenea, Digenea, Nematoda, and Myxosporea. Of these, monogeneans (n = 206) also presented higher numbers of specimens with the abundance of the other groups of parasites. Two species of Monogenea were identified: *Aphanoblastella robustus* Mizelle & Kritsky 1969 and *A. mastigatus* Suriano 1986 parasitizing the gills and surface. A single specimen belonging to the Digenea subclass was identified parasitizing the liver of only one host: *Phyllodistomum rhamdiae* Amato & Amato 1993. Likewise, a progenetic metacercariae of *Crocodilicola pseudostoma* Willemoes-Suhm 1870 was identified in only one host parasitizing the liver, swimming bladder, cavity, intestine, and stomach. Cysts containing myxozoan spores of the *Henneguya jundiai* Negrelli, Vieira, Tagliavini, Abdallah & Azevedo 2019 were found in the gill arches and three species belonging to the Nematoda phylum were collected in the intestine and cavity of only one specimen of host: *Contracaecum* sp. Railliet & Henry 1912, *Rhabdochona* sp. Railliet 1916 and Capillariidae gen. sp. Railliet 1915.

The prevalence, mean intensity, mean abundance, and frequency dominance was higher for *Scleroductus* sp. (Table I) in *P. maculatus*. In *R. quelen*, the monogenean *A. robustus* had higher prevalence, mean abundance, and frequency dominance; however, the metacercaria *C. pseudostoma* had higher mean intensity (Table II).

*Scleroductus* sp. was considered a central species, *N. pimelodi* was considered a secondary species, and all the other parasite species were considered satellites. All parasites had aggregate distribution (Table III).

The results obtained by Pearson ($r$) and Spearman ($rs$) correlation coefficient showed that had the positive correlations in relation to weight of the *P. maculatus* with the prevalence of *D. majusculus* ($rs$= 0.87, $p$= 0.03); however, in *R. quelen* was observed positive correlation to the length and weight with the abundance of endoparasites ($r$= 0.63, $p$= 0.00; $r$= 0.87, $p < 0.05$) and with the parasite *A. mastigatus* ($r$= 0.51, $p$= 0.00; $r$= 0.68, $p < 0.05$).

The results obtained by ANOVA ($F$= 4.12, $p$= 0.03), Tukey significance ($Q$= 4.28, $p$= 0.01) and Kruskal-Wallis ($H$= 4.90, $p$= 0.09) tests showed significance with male specimens of *P. maculatus*. However, in *R. quelen* the results by ANOVA ($F$= 0.18, $p$= 0.84), Tukey significance ($p >$ 0.05) and Kruskal-Wallis ($H$= 0.91, $p$= 0.50) tests showed no significance.

The results for the Dunn's Post-Hoc test, which, the effect sex of the *P. maculatus* and *R. quelen* with the ectoparasite abundance ($p$= 0.03) ($p$= 0.04) respectively, showed significance with immature specimens of both host species and with endoparasites abundance ($p >$ 0.05) showed no significance.

The parasitic diversity indexes determined for each parasitic infracommunity of hosts *P.*

**Table I. Metazoan parasites of *Pimelodus maculatus* Lacépède, 1803 collected in the Jacaré-Pepira River, Ibitinga, state of São Paulo, Brazil.**

| | | PF | PC | P (%) | FD (%) | MI | MA | II |
|---|---|---|---|---|---|---|---|---|
| **Monogenea** | ***Demidospermus majusculus*** | 6 | 95 | 18.75 | 6.25 | 15.83 ± 1.24 | 2.97 ± 0.23 | Gills and surface |
| | ***Demidospermus bidiverticulatum*** | 7 | 55 | 21.88 | 3.13 | 7.86 ± 0.47 | 1.72 ± 0.10 | Gills and surface |
| | ***Demidospermus* sp.** | 6 | 56 | 18.75 | 3.13 | 9.33 ± 0.65 | 1.75 ± 0.12 | Gills and surface |
| | ***Demidospermus paravalenciennesi*** | 1 | 8 | 3.13 | 0 | 8.00 | 0.25 ± 0.04 | Gills and surface |
| | ***Ameloblastella paranaensis*** | 4 | 71 | 12.50 | 3.13 | 17.75 ± 1.88 | 2.22 ± 0.23 | Gills and surface |
| | ***Scleroductus* sp.** | 25 | 1182 | 78.13 | 75.00 | 47.28 ± 1.54 | 36.94 ± 1.20 | Gills and surface |
| **Acanthocephala** | ***Neochinorhynchus pimelodi*** | 21 | 165 | 65.63 | 9.38 | 7.86 ± 0.42 | 5.16 ± 0.28 | Intestine and stomach |
| **Digenea** | ***Austrodiplostomum compactum*** | 4 | 7 | 12.50 | 0 | 1.75 ± 0.16 | 0.22 ± 0.02 | Eyes |
| **Hirudinea** | ***Helobdella* sp.** | 7 | 156 | 21.88 | 6.25 | 22.29 ± 2.89 | 4.88 ± 0.63 | Surface, gills and mouth |
| **Isopoda** | ***Riggia* sp.** | 1 | 1 | 3.13 | 0 | 1.00 | 0.03 ± 0.01 | Surface |

**PF = number of parasitized fish; PC = number of parasites collected; P (%) = prevalence; FD= frequency of dominance; MI = mean intensity with standard deviation; MA = mean abundance with standard deviation; II = site of infestation/infection.**

*maculatus* and *R. quelen*: Brillouin (diversity); Margalef (richness); Pielou (equitability) and Berger-Parker (dominance) are presented in Table IV.

Representative specimens of the parasites *Demidospermus majusculus* (346L), *D. bidiverticulatum* (347L), *Demidospermus* sp. (348L), *D. paravalenciennesi* (349L), *Ameloblastella paranaensis* (350L), *Scleroductus* sp. (351L), *Neochinorhynchus pimelodi* (352L), *Austrodiplostomum compactum* (353L), *Helobdella* sp. (354L), *Aphanoblastella robustus* (355L), *A. mastigatus* (356L), *Crocodilicola pseudostoma* (357L), *Phyllodistomum rhamdiae* (358L), *Riggia* sp. (8187), *Contracaecum* sp. (8188) were deposited in the helminthological collection of the Instituto de Biociências, at the Universidade Estadual Paulista "Julio de Mesquita Filho", campus Botucatu, state of São Paulo, Brazil.

## DISCUSSION

The parasitic community of *P. maculatus* and *R. quelen* was studied by some authors in different hydrological systems (Table V).

According to Halvorsen (1971) and Wootten (1973) the relationship between hosts and parasites is constant, even if they have limnological or geographical differences; thus, we can observe in the present study that there

**Table II.** Metazoan parasites of *Rhamdia quelen* Quoy & Gaimard, 1824 collected in the Jacaré-Pepira River, Ibitinga, state of São Paulo, Brazil.

| | | PF | PC | P (%) | FD (%) | MI | MA | II |
|---|---|---|---|---|---|---|---|---|
| **Monogenea** | ***Aphanoblastella robustus*** | 5 | 119 | 16.67 | 16.67 | 23.80 ± 3.54 | 3.97 ± 0.59 | Gills and surface |
| | ***Aphanoblastella mastigatus*** | 4 | 87 | 13.33 | 6.67 | 21.75 ± 2.39 | 2.90 ± 0.32 | Gills and surface |
| **Digenea** | ***Crocodilicola pseudostoma*** | 1 | 68 | 3.33 | 3.33 | 68.00 | 2.27 ± 0.41 | Liver, swim bladder, cavity, intestine and stomach |
| | ***Phyllodistomum rhamdiae*** | 1 | 1 | 3.33 | 3.33 | 1.00 | 0.03 ± 0.01 | Liver |
| **Myxosporea** | ***Henneguya jundiai*** | 3 | - | 10.00 | - | - | - | Gill arches |
| **Nematoda** | ***Contracaecum* sp.** | 1 | 8 | 3.33 | 0.00 | 8.00 | 0.27 ± 0.05 | Cavity and intestine |
| | **Capillariidae gen. sp.** | 1 | 1 | 3.33 | 0.00 | 1.00 | 0.03 ± 0.01 | Cavity |
| | ***Rhabdochona* sp.** | 1 | 1 | 3.33 | 0.00 | 1.00 | 0.03 ± 0.01 | Cavity |

**PF = number of parasitized fish; PC = number of parasites collected; P (%) = prevalence; FD= frequency of dominance; MI = mean intensity with standard deviation; MA = mean abundance with standard deviation; II = site of infestation/infection.**

is a similarity in the parasitic groups of *P. maculatus* and *R. quelen* compared to the other basins already studied.

The structure of the parasitic community of *P. maculatus* and *R. quelen* was analyzed from the hypothesis of Caswell (1978) and Hanski (1982, 1991), in which they determined the community status of the parasites and suggested that the central species are abundant to achieve equilibrium, but satellite species are less abundant and consequently are not very frequent in the parasitic community (Bush & Holmes 1986), while, the secondary species are those intermediate between the central and satellite species in terms of parasite abundance.

The parasitic community of *P. maculatus* and *R. quelen* presented a typical distribution pattern (aggregate). In general, in the studies of parasite infections in vertebrate hosts, it is common for parasites to show the aggregate distribution in their hosts. This distribution pattern is considered typical in freshwater fish parasites; however, this distribution acts to increase the regulation of the density and abundance of hosts and parasites and also to decrease interspecific competition among parasites (Von Zuben 1997). The leading cause of aggregate distribution is related to random environmental factors, such as the physical changes of the environment in time and space and the hosts' sensitivity to the infection, is associated with the immunological, behavioral, or microhabitat alterations and genetic factors; therefore, changes in microhabitats and hereditary factors may influence the mortality of both parasites and hosts and may also develop

**Table III. Dispersion index (ID) and statistical test d of the metazoan parasites (with a prevalence greater than 10%) of *Pimelodus maculatus* Lacépède, 1803 and *Rhamdia quelen* Quoy & Gaimard, 1824 collected in the Jacaré-Pepira River, Ibitinga, state of São Paulo, Brazil.**

| | | ID | d | Distribution |
|---|---|---|---|---|
| *Pimelodus maculatus* | ***Demidospermus majusculus*** | 18.50 | 26.06 | Aggregate |
| | ***Demidospermus bidiverticulatum*** | 6.35 | 12.03 | Aggregate |
| | ***Demidospermus* sp.** | 8.81 | 15.56 | Aggregate |
| | ***Ameloblastella paranaensis*** | 25.41 | 31.87 | Aggregate |
| | ***Scleroductus* sp.** | 39.89 | 41.92 | Aggregate |
| | ***Neochinorhynchus pimelodi*** | 15.25 | 22.93 | Aggregate |
| | ***Austrodiplostomum compactum*** | 1.99 | 3.26 | Aggregate |
| | ***Helobdella* sp.** | 83.87 | 64.27 | Aggregate |
| | | | | |
| *Rhamdia quelen* | ***Aphanoblastella robustus*** | 79.07 | 60.17 | Aggregate |
| | ***Aphanoblastella mastigatus*** | 31.42 | 35.14 | Aggregate |

diversity in the dispersion of parasites within the host population (Von Zuben 1997). Anderson & Gordon (1982) proposed that the aggregation levels of the parasites present inversely proportional variation to the pathogenicity of the parasite because the highly pathogenic parasites have a higher possibility of causing the death of the hosts that show medium or high levels of parasites and with this cause, a uniform distribution of the pests, reducing the aggregation of the parasites in their hosts. According to these authors, the factors that generate the uniform distribution are the mortality of parasites, density-dependent processes as well as death of the host when caused by the parasite, that is, when the host death occurs due to the high parasitic load, however, concerning the factors that generate the aggregate distribution is involved the diversity in the tendency of the host to the infection, direct reproduction of the parasite in the host, as well as the diversity of the ability of the hosts to eliminate the parasites by immunological responses.

The length and weight of *R. quelen* correlated with the abundance of endoparasites and this result was obtained because all the endoparasites were collected only in two hosts, whose which presented longer length (23.50 and 30.50 cm) and higher weight (171.05 and 414.61 g) concerning other specimens of fish analyzed. We can verify the influence of the length of *R. quelen* specimens with the abundance of endoparasites, and according to Von Zuben (1997) the range of the host is one of the main factors correlated with the parasite abundance because the larger length hosts often have a higher food consumption compared to hosts with smaller length and the larger length hosts can provide more space for the parasites to lodged and consequently lodged several species. The age of the host is demonstrated concerning the length

and this mainly acts in the variation of the size of the parasitic infrapopulation, however these variations in the parasitic fauna according to the age of the hosts can also be related to immunological and ecological factors, like alteration in the diet and fish migration (Dogiel 1961). According to Bell & Burt (1991), the diversity of endoparasites may be related to the size, age, and diet of the host; however, this relationship between endoparasite diversity and host length indicates that there are significant variations in food habits of the host according to its growth.

In *P. maculatus*, ectoparasites and endoparasites were more abundant in immature specimens. However, the juvenile specimens of *R. quelen* presented lower parasitic abundance, ectoparasites were more abundant in males, while endoparasites were more abundant in females.

There are several studies carried out in Brazil (Saad & Luque 2009, Dias et al. 2010, Fontenelle et al. 2015, Rodrigues et al. 2015, Santos & Alves 2016, Serrano et al. 2017), as well as in other countries (Grabda 1983, Chao 1985, Mattiucci et al. 2002, Fei et al. 2004, Su & Fei 2004, Kozačinski et al. 2006, Iglesias et al. 2008, Palm et al. 2008), in which they reported that the fish were parasitized by nematodes with zoonotic potential, main nematodes of the family Anisakidae.

The nematodes of the genus *Contracaecum* belong to the family Anisakidae and are economically essential parasites because they have zoonotic potential, this genus parasite the fish as larvae, that is, it uses the fish as an intermediate host. However, these parasites when adults lodged in the stomach/intestine of piscivorous birds or marine mammals. The larvae of *Contracaecum* regularly adhering to the viscera of the fish can migrate to the muscle after the death of the host, this occurs when the fish are not frozen at the optimal temperature (Bier 1988, Carvalho et al. 2010, Souza et al. 2016). However, it is vital to take the necessary care when preparing and consuming raw or undercooked fish, such as "sushi," "sashimi" and "ceviche", because the larvae ($L_3$) of the parasite may cause a parasitic syndrome in humans, that is, anisakidosis. The pathology in humans will depend on the region or location in which the larva of the parasite will lodge, thus, the disease may be luminal when the worms are deposited inside the organs asymptomatically without causing damage, and after the larva's death it will be eliminated in the feces (Ramos 2011, Souza et al. 2016); when the worm lodged is in the gastrointestinal tract can cause pain, diarrhea, and nausea; in some cases when larvae are deposited in the wall of the mucosa, may manifest allergic reactions due to the toxins produced by the parasite (Moneo et al. 2000, Martins et al. 2005, Souza et al. 2016, Shamsi et al. 2018) and in cases of chronic subacute form, the larvae may migrate and lodged to other organs such as lung, liver, spleen, and pancreas (Nunes et al. 2003, Souza et al. 2016). In Brazil, there is only one report of anisakidosis in humans, in which the contaminated person consumed raw shellfish in Bahia state three weeks before the symptoms (Cruz et al. 2010) and according to Kim et al. (2006) the absence of other reports in Brazil may be related to the difficulty of diagnosing the disease, because the case is confirmed only when through the diagnosis, it visualizes the presence of larvae of the parasite of the family Anisakidae.

Dias et al. (2016) studied the helminth parasites in southern Brazil, in which they also found nematodes of the genus *Contracaecum* anisakids, the infections may be related to the environmental factors, such as temperature, that may influence the development of parasite eggs, as well as other factors, such as the age, size, and diet of hosts (Torres et al. 2000, Carvalho

**Table IV. Parasite diversity indexes determined for the parasitic infracommunity of *Pimelodus maculatus* Lacépède, 1803 and *Rhamdia quelen* Quoy & Gaimard, 1824 collected in the Jacaré-Pepira River, Ibitinga, state of São Paulo, Brazil.**

| | ***Pimelodus maculatus*** | ***Rhamdia quelen*** |
|---|---|---|
| **Brillouin (H)** | 1.18 ± 1.30 (1.24) | 1.12 ± 1.26 (1.19) |
| **Margalef *(d)*** | 1.20 ± 1.20 (1.20) | 0.88 ± 1.06 (1.06) |
| **Pielou (J)** | 0.52 ± 0.57 (0.54) | 0.61 ± 0.70 (0.63) |
| **Berger-Parker *(d)*** | 0.68 ± 0.30 (0.66) | 0.30 ± 0.47 (0.42) |

**Values in parentheses are the mean.**

et al. 2015). Madi & Silva (2005) analyzed the infections of the parasite *Contracaecum* sp. in *R. quelen* and was observed that the presence of this parasite is more intense in fish with longer length than 20.00 cm (Carvalho et al. 2015), we can also find this in the present study because the host parasitized by *Contracaecum* sp. was the most extended (30.50 cm) about the other 29 fish analyzed.

According to parasitic diversity indexes results, indicate that the parasitic community of *P. maculatus* and *R. quelen* is characterized by high diversity, high richness, and low uniformity, this can be explained by the high number of parasite species found in both species of fish; *P. maculatus* (10 species) and *R. quelen* (eight species) and also for the high abundance found in most species of parasites, however, obtained a low uniformity because the parasites presented an aggregate distribution. According to Bush et al. (1997) the meaning of diversity in the composition of a community in terms of the number of species present and some factor that changes the relative equality of the distribution of each species because the species are not the same, some may have a high, medium or rare abundance. Besides, this diversity can be divided into richness, which is the number of species present in a single host and in uniformity, in which it reports how much the abundance of the species is variable, in this case, a community in which all species has the approximately same number of individuals can be considered with high uniformity and when there is a significant difference in the abundance of the species has the effect of a low uniformity (Magurran 1988). According to Von Zuben (1997), the diversity of parasites may also be related to the variety of intermediate and definitive hosts.

The mean of the Berger-Parker dominance index was higher in the host *P. maculatus* 0.68 ± 0.30 compared to the *R. quelen* host 0.30 ± 0.47, and according to Ingram (2008) the Berger-Parker dominance index determines the higher abundance of individuals in the species of parasite that presented in the ecological community; thus, *P. maculatus* had parasite species that showed a higher richness, compared to the abundance of the parasite species collected in *R. quelen*.

In the two species of fish analyzed, ectoparasites were more prevalent compared to endoparasites. According to Pavanelli et al. (2004), the monogeneans are more frequent in environments considered lentic, because these environments contribute to the transmission of these parasites that have a direct life cycle so that free-swimming monogenean larvae to find the host more easily (Dogiel 1961). According to Kennedy (1982), abiotic factors such as depth, habitat, pollution, and temperature of rivers, are the main that affect abundance and prevalence parasitic. Thus, the predominance of monogeneans in *P. maculatus* and *R. quelen* may be related to the habitat of these hosts collected in a lentic environment and also for the habit of these fish, because they remain at the bottom of the rivers, providing a greater contact with the monogeneans.

**Table V. World checklist of parasites *of Pimelodus maculatus* Lacepède, 1803 and *Rhamdia quelen* Quoy & Gaimard, 1824.**

| Parasites | Host | infection / infestation | Locality | Reference |
|---|---|---|---|---|
| **Acanthocephala** | | | | |
| *Pomphorhynchus sphaericus* | PM | - | Argentina | Pertierra et al. (1996) |
| *Neoechinorhynchus pimelodi* | PM | Intestine | Brazil | Brasil-Sato & Pavanelli (1998, 1999), Lopes et al. (2011) |
| *Neoechinorhynchus* sp. | RQ | Intestine | Brazil | Morais (2005) |
| *Quadrigyrus machadoi* | PM | Intestine | Brazil and Argentina | Takemoto et al. (2009), Chemes & Brusa (2013) |
| *Polymorphus* sp. | RQ | Intestine | Brazil | Morais (2005), Azevedo et al. (2010) |
| *Centrorhynchus* sp. | RQ | Mesentery | Brazil | Morais (2005) |
| **Hirudinea** | | | | |
| *Helobdella* sp. | PM | Gill | Brazil | Brasil-Sato (2003), Santos et al. (2007), Takemoto et al. (2009) |
| *Myzobdella* sp. | PM | Gill | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Myzobdella uruguaiensis* | RQ | Gill | Brazil | Morais (2005) |
| **Copepoda** | | | | |
| *Ergasilus chelangulatus* | PM | Gill | Brazil | Thatcher & Brasil-Sato (2008) |
| *Ergasilus thatcheri* | RQ | Gill | Brazil | Engers et al. (2000) |
| *Gamispinus diabolicus* | PM | Nasal cavitie | Brazil | Brasil-Sato et al. (2000), Brasil-Sato (2003), Luque et al. (2013) |
| *Gamidactylus* sp. | PM | - | Brazil | Takemoto et al. (2009), Luque et al. (2013) |
| *Therodamas* sp. | PM | Gill | Brazil | Brasil-Sato (2003), Takemoto et al. (2009), Luque et al. (2013) |
| *Vaigamus* sp. | PM | - | Brazil | Brasil-Sato (2003), Takemoto et al. (2009), Luque et al. (2013) |
| *Lernaea cyprinacea* | RQ | Pectoral fins and buccal cavity | Brazil | Furtado et al. (2019) |
| **Isopoda** | | | | |
| *Telotha* sp. | PM | Gill | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Riggia* sp. | RQ | Abdominal cavity | Ecuador | Anaguano-Yancha & Brito (2015) |
| **Cestoda** | | | | |
| *Endorchis* sp. | PM | Intestine | Paraguay | Chambrier & Vaucher (1999) |
| *Monticellia loyolai* | PM | Intestine | Brazil | Pavanelli & Machado dos Santos (1992), Brasil-Sato (2003) |

**Table V.** Continuation

| Parasites | Host | infection / infestation | Locality | Reference |
|---|---|---|---|---|
| *Nomimoscolex microacetabula* | PM | Intestine | Argentina | Pertierra (1995) |
| *Nomimoscolex pimelodi* | PM | Intestine | Argentina | Pertierra (1995) |
| *Nomimoscolex* sp. | PM | Intestine | Brazil | Brasil-Sato (2003), Santos et al. (2007), Albuquerque et al. (2008), Takemoto et al. (2009), Azevedo et al. (2010) |
| *Monticellia magna* | PM | Intestine | Argentina | Pertierra (2004) |
| *Goezeella agostinhoi* | PM | Intestine | Brazil | Bachmann et al. (2007) |
| *Valipora* sp. | PM | Gallbladder | Brazil | Takemoto et al. (2009) |
| *Proteocephalus bagri* | RQ | Intestine | Argentina | Pertierra (2002) |
| *Proteocephalus rhamdiae* | RQ | Intestine | Argentina | Pertierra (2002) |
| **Digenea** | | | | |
| *Crepidostomum platense* | PM | Estomach and intestine | Brazil and Argentina | Kohn & Fróes (1986), Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009), Núñez et al. (2017) |
| *Creptotrema creptotrema* | PM | Intestine | Brazil | Kohn & Fróes (1986), Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009) |
| *Parspina argentinensis* | PM | Estomach and intestine | Brazil and Argentina | Kohn & Fróes (1986), Bachmann et al. (2007), Núñez et al. (2017) |
| *Thometrema overstreeti* | PM | Estomach and intestine | Brazil | Kohn et al. (1990), Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009) |
| *Plehniella coelomica* | PM | Cavity celomatic | Brazil | Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009) |
| *Prosthenhystera obesa* | PM | Gallbladder | Brazil | Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009) |
| *Clinostomum* sp. | PM | Gill Muscle | Brazil | Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Takemoto et al. (2009) |
| *Clinostomum complanatum* | RQ | Muscle, gill, fins and eyes | Brazil | Morais (2005), Vianna et al. (2005), Dias et al. (2016) |
| *Clinostomum detruncatum* | RQ | - | Brazil | Azevedo et al. (2010) |
| *Diplostomum* sp. | PM | Eyes, cephalic renal parenchyma, bladder musculature and pharyngeal plate | Brazil | Brasil-Sato (2003), Brasil-Sato & Pavanelli (2004), Bachmann et al. (2007), Takemoto et al. (2009) |

**Table V.** Continuation

| Parasites | Host | infection / infestation | Locality | Reference |
|---|---|---|---|---|
| *Austrodiplostomum compactum* | PM | Eyes | Brazil | Santos et al. (2007) |
| *Genarchella parva* | PM/ RQ | Stomach | - | Núñez et al. (2017) |
| *Genarchella* sp. | RQ | Stomach, intestine | Brazil | Morais (2005), Dias et al. (2016) |
| *Crocodilicola pseudostoma* | RQ | Body cavity | Brazil | Armas de Conroy (1986) |
| *Phyllodistomum rhamdiae* | RQ | Urinary bladder | Brazil | Amato & Amato (1993) |
| *Tylodelphys destructor* | RQ | Celtic cavity, cephalic kidney, heart, swim bladder, gonad and intestine | Brazil | Morais (2005), Dias et al. (2016) |
| *Acanthostomum* sp. | RQ | Stomach and intestine | Brazil | Morais (2005), Dias et al. (2016) |
| **Monogenea** | | | | |
| *Ameloblastella platensis* | PM | Gill | Argentina and Brazil | Suriano & Incorvaia (1995), Monteiro et al. (2010) |
| *Ameloblastella paranaensis* | PM | Gill | Brazil | Monteiro et al. (2010) |
| *Ameloblastella satoi* | PM | Gill | Brazil | Monteiro et al. (2010) |
| *Ameloblastella chavarriai* | RQ | Gill | - | Thatcher (2006) |
| *Aphanoblastella* sp. | PM/ RQ | Gill | Brazil | Venancio et al. (2010) |
| *Aphanoblastella juizforense* | RQ | Gill | Brazil | Carvalho et al. (2009) |
| *Aphanoblastella mastigatus* | RQ | Gill | Brazil | Azevedo et al. (2010) |
| *Demidospermus* sp. | PM | Gill | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Demidospermus bidiverticulatum* | PM | Gill | Argentina and Brazil | Kritsky & Gutiérrez (1998), Gutiérrez & Martorelli (1999a, b), Cohen & Kohn (2008), Monteiro et al. (2010) |
| *Demidospermus paravalenciennesi* | PM | Gill | Argentina and Brazil | Kritsky & Gutiérrez (1998), Gutiérrez & Martorelli (1999a, b), Santos et al. (2007), Cohen & Kohn (2008), Azevedo et al. (2010), Monteiro et al. (2010) |
| *Demidospermus uncusvalidus* | PM | Gill | Argentina and Brazil | Kritsky & Gutiérrez (1998), Gutiérrez & Martorelli (1999a, b), Santos et al. (2007), Monteiro et al. (2010) |
| *Demidospermus armostus* | PM | Gill | Argentina and Brazil | Gutiérrez & Martorelli (1999a, b), Cohen & Kohn (2008), Azevedo et al. (2010), Monteiro et al. (2010) |

**Table V.** Continuation

| Parasites | Host | infection / infestation | Locality | Reference |
|---|---|---|---|---|
| *Demidospermus majusculus* | PM | Gill | Brazil | Santos et al. (2007) |
| *Demidospermus ichthyocercus* | PM | Gill | Brazil | Monteiro et al. (2010) |
| *Demidospermus leptosynophallus* | PM | Gill | Brazil | Azevedo et al. (2010) |
| *Pavanelliella pavanellii* | PM | Nasal cavity | Brazil | Brasil-Sato & Pavanelli (2000) |
| *Pavanelliella takemotoi* | PM | Nasal cavity | Brazil | Aguiar et al. (2011) |
| *Unibarra* sp. | PM | Gill | Brazil | Takemoto et al. (2009) |
| *Unibarra paranoplatensis* | PM | Gill | Argentina | Suriano & Incorvaia (1995), Negreiros et al. (2019) |
| *Scleroductus* sp. | PM/ RQ | Gill | Brazil | Kritsky et al. (1995, 2013), Ferrari-Hoeinghaus et al. (2006), Santos et al. (2007) |
| *Scleroductus yuncensi* | PM | Gill | Argentina | Gutiérrez & Martorelli (1999a, b) |
| *Kritskyia moraveci* | RQ | Urinary bladder and ureters | Brazil | Kohn (1990) |
| *Urocleidoides mastigatus* | RQ | Gill | Brazil | Ferrari-Hoeinghaus et al. (2006) |
| *Gyrodactylus lilianae* | RQ | Surface, fins and barbels | Brazil | Razzolini et al. (2019) |
| **Myxozoan** | | | | |
| *Henneguya* sp. | PM | Gill | Brazil | Martins et al. (2004), Bachmann et al. (2007), Santos et al. (2007) |
| *Henneguya rhamdia* | RQ | Gill | Brazil | Matos et al. (2005) |
| *Henneguya jundiai* | RQ | Gill | Brazil | Negrelli et al. (2019) |
| *Myxobolus* sp. | PM | Gill | Brazil | Cordeiro et al. (1989) |
| *Myxobolus absonus* | PM | Gill and opercular cavity | Brazil | Cellere et al. (2002), Santos et al. (2007) |
| *Myxobolus marajoensis* | RQ | Intestine | Brazil | Abrunhosa et al. (2017) |
| **Nematoda** | | | | |
| *Rhaphidascaris (Sprentascaris) pimelodi* | PM | Intestine | Paraguay | Petter & Cassone (1984) |
| *Spinitectus sternopygi* | PM | - | - | Thatcher (1991) |
| *Cucullanus* sp. | PM/ RQ | Intestine | Brazil | Brasil-Sato (2003), Azevedo et al. (2010), Luque et al. (2011) |
| *Cuccullanus patoi* | PM | Intestine | Brazil | Fortes et al. (1992), Luque et al. (2011) |

**Table V. Continuation**

| Parasites | Host | infection / infestation | Locality | Reference |
|---|---|---|---|---|
| *Cucullanus fabregasi* | PM | Intestine | Brazil | Fortes et al. (1993a), Luque et al. (2011) |
| *Cucullanus riograndensis* | PM | Intestine | Brazil | Fortes et al. (1993b), Luque et al. (2011) |
| *Cucullanus debacoi* | PM | Intestine | Brazil | Sarmento et al. (1995), Luque et al. (2011) |
| *Cucullanus pinnai* | PM/ RQ | Stomach, celomatic cavity, intestine | Brazil | Vicente & Pinto (1999), Brasil-Sato (2003), Santos et al. (2007), Albuquerque et al. (2008), Takemoto et al. (2009), Venancio et al. (2010) |
| *Contracaecum* sp. | PM/ RQ | Mesentery, gonada, stomach, intestine and liver | Brazil | Brasil-Sato (2003), Madi & Silva (2005), Takemoto et al. (2009), Azevedo et al. (2010), Dias et al. (2016) |
| *Goezia* sp. | PM | Intestine | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Goezia spinulosa* | PM | Stomach | - | Luque et al. (2011) |
| *Dichelyne* sp. | PM | Intestine | Brazil | Brasil-Sato (2003) |
| *Dichelyne pimelodi* | PM | Intestine | Brazil | Moravec et al. (1997), Bachmann et al. (2007), Luque et al. (2011) |
| *Philometra* sp. | PM | - | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Monhysterides* sp. | PM | Intestine | Brazil | Takemoto et al. (2009) |
| *Procamallanus (Spirocamallanus)* sp. | PM | Intestino | Brazil | Vicente & Pinto (1999), Takemoto et al. (2009) |
| *Procamallanus (Spirocamallanus) freitasi* | PM | Intestine | Brazil | Brasil-Sato (2003) |
| *Procamallanus (Spirocamallanus) pimelodus* | PM | Intestino | Brazil | Bachmann et al. (2007) |
| *Procamallanus (Spirocamallanus) rarus* | PM | Intestino | - | Yamada & Takemoto (2013) |
| *Procamallanus (Spirocamallanus) hilarii* | RQ | - | - | Luque et al. (2011) |
| *Eustrongylides* sp. | PM | Body cavity | Brazil | Brasil-Sato (2003), Takemoto et al. (2009) |
| *Rondonia rondoni* | PM | - | - | Luque et al. (2011) |
| *Rhabdochona uruyeni* | PM | Intestine | Brazil | Azevedo et al. (2010) |
| Rhabdochona kidderi | RQ | - | Mexico | Moravec et al. (2012) |
| Capillariidae gen. sp. | RQ | - | Brazil | Azevedo et al. (2010) |
| *Hysterothylacium* sp. | RQ | Stomach and intestine | Brazil | Dias et al. (2016) |

**PM= *Pimelodus maculatus*; RQ= *Rhamdia quelen.***

## CONCLUSION

The nematode of the genus *Contracaecum* sp., which has zoonotic potential, was collected parasitizing *R. quelen*. However, greater attention should be paid to this parasite in *R. quelen*, as this fish has economic importance for fishing and has been used in the preparation of "sushi" and "sashimi", therefore, if *Contracaecum* sp. parasitizes these fish, they can cause consequences in humans depending on the way the fish is consumed, presenting the symptoms already discussed previously. We can observe different groups of parasites in both *P. maculatus* and *R. quelen*; however, ectoparasites were predominant in the two host species. Some of the parasites had their first registration in the host, as the Isopoda *Riggia* sp. is a new record for the host *P. maculatus* and *A. robustus* is a new record for the host *R. quelen* and all the parasites collected in the two species of fish are new records for the Jacaré-Pepira River, Ibitinga.

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## Author contributions

Negrelli DC performed fish analysis, parasite processing and revised the manuscript. Iannacone J performed the statistical analyzes and revised the manuscript. Abdallah VD & Azevedo RK constituted and revised the manuscript, as well as, identified the species of parasites found.

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