Community of Monogenea in populations of *Cichla monoculus* from two tributaries of the Amazon River in the Northern Brazil

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**Summary**

This study compared the monogeneans community in *C. monoculus* from the Tapajós River (state of Pará) and Jari River (state of Amapá), northern Brazil. A total of 2188 monogeneans belonging to eight taxa were collected from the gills of fish: *Gussevia arilla*, *Gussevia longihaptor*, *Gussevia tucunarense*, *Gussevia undulata*, *Sciadicleithrum ergensi*, *Sciadicleithrum umbilicum*, *Sciadicleithrum uncinatum* and *Tucunarella cichlae*. *Gussevia arilla* was the dominant species for *C. monoculus* from the Tapajós River basin, while *S. umbilicum* predominated among the hosts from the Jari River basin. For the two populations of *C. monoculus*, the prevalence, mean intensity and mean abundance of monogeneans were different and the parasitic community had a high qualitative similarity (87.5 %). The monogeneans community of *C. monoculus* was characterized by high species richness, with infection values varying from low to moderate. The geographic distance and differences in environmental characteristics arising from the same did not influence the richness of species of monogeneans infesting *C. monoculus* in the Tapajós and Jari rivers, but appear to have been determinants in the differences observed in the structure of the monogenean communities in each region.

**Keywords:** Ectoparasites; Jari River; Monogenean; Peacock bass; Tapajós River; Tucunaré

**Introduction**

The Tapajós River basin is formed from the confluence of the Teles Pires River and the Juruena River in the state of Mato Grosso, and flows into the middle Amazon River, in the region of Santarém, in the state of Pará (Umetsu *et al.*, 2007). It has transparent waters and due to its distance from the sea (around 650 km) suffers little influence from the tide of the Amazon River. The Jari River basin, meanwhile, is formed in the Tumucumaque Mountains National Park, on the border between Brazil and Suriname, and flows into the lower Amazon River in the south of the state of Amapá (Amapá, 2012). Its mouth is around 270 km of the Atlantic Ocean, and suffers strong influence of tides of the Amazon River. For this reason, the Jari River it has white waters downstream and black waters upstream, varying the amount of organic matter in suspension (Abreu & Cunha, 2015).

The genus *Cichla* Block & Schneider, 1801 (Cichlidae) comprise 15 fish species that are popularly known as peacock bass. They are endemic to the Amazon River system and, due to the excellence of their meat are important in extractive fishery and fish farming (Batista & Petrere Júnior, 2003; Kullander & Ferreira, 2006; Santos *et al.*, 2012). *Cichla monoculus* is widely distributed in the
Amazon region and can be found from Peru to French Guiana (Kullander & Ferreira, 2006). Due to the importance in the sport fishing, some species of *Cichla* have been introduced in other Brazilian river basins (Agostinho & Júlio Júnior, 1999; Chellappa et al., 2003; Gomiero & Braga, 2004). Studies on parasites of wild fish populations, in addition to increasing knowledge of diversity, can generate information about the parasite-host-environment relationship (Oliveira et al., 2016; Oliveira & Tavares-Dias, 2016). In addition, some studies have tried to elucidate the main factors that influence the parasite composition of host population (Poulin, 1995; Poulin et al., 1999; Marcogliese et al., 2006; Braicovich & Timi, 2008; Francová & Ondráčková, 2011; Santana-Pineros, et al., 2012; Lagrue & Poulin, 2015; Marcogliese, et al., 2016). Monogenea Van Beneden, 1858, which belongs to the Platyhelminthes Gegenbaur, 1859 phylum, is the most diverse group of parasites, with around 835 species described parasitizing fish from South America (Luque et al., 2017). While these are mainly ectoparasites of fish, and are usually found on gills, body surface and nasal cavities, but some species are endoparasites inhabiting the intestine, stomach and urinary bladder of hosts (Bilong-Bilong, et al., 1996; Guidelli et al., 2003a; Boeger & Viana, 2006). They exhibit high host specificity in comparison with

![Map of the Amazon River basin](image)

**Fig. 1.** Sampling sites of *Cichla monoculus* in the tributaries from the Amazon River, in eastern Amazon, Northern Brazil.
other helminths taxa (Boeger & Viana, 2006; Braga et al., 2014). In Brazil, most of the monogenean species described from freshwater fish belong to the Dactylogyridae and Gyrodactylidae families, with the dominance of dactylogyrid species (Cohen et al., 2013; Luque et al., 2017). Among fish from the Cichlidae family, infestations were recorded mainly by dactylogyrid species (Cohen et al., 2013; Ferreira-Sobrinho & Tavares-Dias, 2016). For the Cichla genus, eight species of monogeneans are known (Cohen et al., 2013), but only Gussevia longihaptor, Tucunarella cichlae (Mendoza-Franco et al., 2010) and Gussevia undulata (Mendoza-Franco et al., 2010) have been recorded parasitizing C. monoculus, and such studies has been restricted to the Peruvian Amazon. Thus, this study compared the community of monogeneans in gills of C. monoculus from the Tapajós and the Jari rivers, both tributaries of the Amazon River system in the northern Brazil.

Materials and Methods

Fish collection

The specimens of C. monoculus were captured in March 2015 in the Jari River, near the community of Jarilândia, in the municipal of Santarém, in the state of Pará, Brazil (2°20’2.58"S - 51°59’43.94”W) (Fig. 1). The 19 specimens from the Jari River measured 29.9 ± 3.7 cm and weighed 737.0 ± 240.1 g. All the specimens from the Jari River were euthanized by spinal cord transection. Their standard length and weight (g) were then measured, and they were necropsied for the removal of the gills, which were transferred to flasks containing heated water (60-70°C) and shaken vigorously for detachment of the parasites (Kritsky & Stockwell, 2005). The collected monogeneans were fixed in formalin 5 % for 24 h and preserved in alcohol 70 %. The methodology used to quantify the parasites was that recommended by Eiras et al. (2006), and identification was in accordance with Kritsky et al. (1986), Kritsky et al. (1989) and Mendoza-Franco et al. (2010).

Data analysis procedures

The prevalence, mean intensity, mean abundancy (Bush et al., 1997) and frequency of dominance, i.e. percentage of infracomunities in which a given species of parasite is numerically dominant were determined (Rohde et al., 1995). The differences in prevalence for each species of monogenean from the host populations were evaluated using the Williams’ G-test with Yates’s correction; and the differences in abundance and intensity were compared using the Mann-Whitney test (U) (Zar, 2010).

To test the differences between the monogenean communities of C. monoculus, Tapajós River and Jari River, the (ANOSIM) test was used with 999 permutations using the similarity index Jaccard (J) (qualitative), and dissimilarity index of Bray-Curtis (B) (quantitative). Principal Component Analysis (PCA) was carried out to compare the monogenean communities in the gills of fish from both hydrographic basins. These analyzes were carried out using the Past-Paleontological Statistics software package (Hammer et al., 2001).

Ethical Approval and/or Informed Consent

The fish capture was authorized by the Ministry of the Environment (SISBIO n° 44268-4) and the methodology of the present study was approved by the Ethics Research Committee of the Universidade Federal de São Paulo (São Paulo Federal University) (CEUA No 92090802140) in accordance with Brazilian legislation (Federal Law 11794, dated October 8, 2008).

Results

The 19 specimens of C. monoculus from the Tapajós River measured 37.4 ± 2.6 cm and weighed 657.5 ± 142.5 g, and the 20 specimens from the Jari River measured 29.9 ± 3.7 cm and weighed 737.0 ± 240.1 g. All the fish examined were parasitized by species of monogeneans one or more species. A total of 561 monogeneans were collected from C. monoculus from the Tapajós River and 1627 from the Jari River, totaling 2188 parasites. These parasites were distributed into the following taxa: Gussevia arilla Kritsky, Thatcher & Boeger, 1986; Gussevia longihaptor Kritsky, Thatcher & Boeger, 1986; Gussevia tucunaremense Kritsky, Thatcher & Boeger, 1986; Gussevia undulata Kritsky, Thatcher & Boeger, 1986; Sciadicleithrum ergensi Kritsky, Thatcher & Boeger, 1989; Sciadicleithrum umbilicum Kritsky, Thatcher & Boeger, 1989; Sciadicleithrum unicinctum Kritsky, Thatcher & Boeger, 1989 and Tucunarella cichlae Mendoza-Franco, Scholz & Rozkošná, 2010. Gussevia arilla was the dominant species in the C. monoculus population from the Tapajós River, and S. umbilicum was the dominant species in hosts from the Jari River. Of these eight species of monogeneans found, seven species were commons for hosts of both basins, but T. cichlae occurred only in hosts from the Tapajós River. The infestation levels of monogenean species varied among themselves and between the regions studied. In hosts from the Tapajós River, the highest values of infestation were caused by G. arilla and S. umbilicum, and in the Jari River by S. umbilicum and S. ergensi. The lowest values of infestation in fish from the Tapajós River were caused by G. undulata and in the Jari River by T. cichlae of (Table 1).
Table 1. Infestation by monogenean species in the gills of *Cichla monoculus* from the Tapajós River and the Jari River in the eastern Amazon, Northern Brazil. P: Prevalence; MI: Mean intensity; MA: Mean abundance; FD: Frequency of dominance; TNP: Total number of parasites. SD: Standard deviation.

| Parasites                  | Tapajós River (N = 19) | Jari River (N = 20) |
|----------------------------|------------------------|---------------------|
|                            | P (%)      | MI      | MA ± SD | FD (%) | TNP | P (%)  | MI      | MA ± SD | FD (%) | TNP  |
| *Gussevia arilla*          | 100        | 10.8    | 10.8 ± 7.3 | 0.363  | 205  | 80     | 11.1    | 8.9 ± 16.2 | 0.109  | 178  |
| *Gussevia longihaptor*     | 42.1       | 2.4     | 1.0 ± 1.6  | 0.034  | 19   | 80     | 6.8     | 5.4 ± 9.2  | 0.066  | 108  |
| *Gussevia tucunarense*     | 100        | 4.1     | 4.1 ± 4.1  | 0.138  | 78   | 55     | 4.3     | 2.3 ± 4.6  | 0.029  | 47   |
| *Gussevia undulata*        | 36.8       | 2.7     | 1.0 ± 1.5  | 0.034  | 19   | 60     | 8.0     | 4.8 ± 6.4  | 0.059  | 96   |
| *Sciadicleithrum ergensi*  | 94.7       | 4.7     | 4.5 ± 3.7  | 0.150  | 85   | 100    | 12.5    | 12.5 ± 9.1 | 0.154  | 250  |
| *Sciadicleithrum umbilicum*| 100        | 5.9     | 5.9 ± 3.7  | 0.200  | 113  | 100    | 41.8    | 41.8 ± 36.5 | 0.514  | 836  |
| *Sciadicleithrum uncinatum*| 68.4       | 3.2     | 2.2 ± 2.7  | 0.074  | 42   | 90     | 5.7     | 5.15 ± 5.4 | 0.063  | 103  |
| *Tucunarella cichlae*      | 0          | 0       | 0        | -      | -    | 35     | 1.3     | 0.45 ± 0.7 | 0.006  | 9    |
There were significant differences in the prevalence, mean intensity and mean abundance of monogeneans for both host populations (Table 2). The monogeneans community of *C. monoculus* of the Tapajós River and Jari River presented homogeneity according to the qualitative index Jaccard ($J = 0.875$) ($R = 0.370$, $p = 0.001$) and quantitative index Bray-Curtis ($B = 0.459$) ($R = 0.643$, $p = 0.001$).

A positive correlation was observed between the abundance of monogeneans in *C. monoculus* (Table 3). In fish from the Tapajós River, were predominant hosts with 5 – 6 species of parasites, while in fish from the Jari River there was a predominance of hosts with 4 – 8 species of monogeneans (Fig. 2). Multivariate analysis of the monogenean communities of *C. monoculus* from the Tapajós and Jari rivers revealed small differences between the host populations, caused by *G. arilla* and *S. umbilicum* (Fig. 3).

**Discussion**

Fish have an important role in the life cycle of various species of monoxenic parasites (Hoffman, 1999; Thatcher, 2006; Oliveira *et al.*, 2016), including monogenean species. These associations are highly complex and dynamic, resulting from the interaction of evolutionary systems and ecological processes acting simultaneously (Alarcos & Timi, 2012). Therefore, phylogenetically proximal fish populations, living in the same environment, can exhibit major similarity in the community and richness of parasite species (Alarcos & Timi, 2012; Hoshino & Tavares-Dias, 2016; Oliveira *et al.*, 2016). In contrast, when great distances separate such host populations, these similarities tend to diminish (Poulin *et al.*, 1995; Poulin & Morand, 1999; Lagoue & Poulin, 2015). The community of monogeneans of *C. monoculus* from the Tapajós River and Jari...
### Table 3. Coefficient of Spearman’s correlation ($rs$), considering ($p \leq 0.05$), between abundance of infracommunities of monogeneans in the gills of *Cichla monoculus* from the Tapajós River and the Jari River in the eastern Amazon, Northern Brazil.

| Tapajós River          | Gussevia arilla | Gussevia longihaptor | Gussevia tucunarense | Gussevia undulata | Sciadicleithrum ergensi | Sciadicleithrum umbilicum | Sciadicleithrum uncinatum | Tucunarella cichlae |
|------------------------|-----------------|----------------------|----------------------|-------------------|------------------------|--------------------------|-------------------------|---------------------|
|                        | $rs$ | $p$       | $rs$    | $p$      | $rs$    | $P$          | $rs$    | $p$      | $rs$    | $p$      | $rs$    | $p$      | $rs$    | $p$      | $rs$    | $p$      |
| Gussevia arilla        | 0.47  | 0.04     | 0.69    | 0.001   | 0.47    | 0.04        | 0.55    | 0.01    | 0.25    | 0.29    | 0.56    | 0.01    | -       | -       |
| Gussevia longihaptor   | 0.37  | 0.12     | 0.14    | 0.57    | 0.24    | 0.31        | 0.28    | 0.25    | 0.49    | 0.03    | -       | -       |
| Gussevia tucunarense   | 0.31  | 0.19     | 0.25    | 0.30    | 0.28    | 0.25        | 0.48    | 0.61    | 0.005   | -       | -       |
| Gussevia undulata      | 0.35  | 0.15     | 0.25    | 0.29    | 0.28    | 0.33        | 0.61    | 0.005   | -       | -       |
| Sciadicleithrum ergensi| 0.41  | 0.08     | 0.62    | 0.004   | -       | -           | -       | -       |
| Sciadicleithrum umbilicum| 0.41 | 0.05     | 0.43    | 0.06    | 0.34    | 0.13        | -       | -       |
| Sciadicleithrum uncinatum| 0.15 | 0.52     | 0.43    | 0.06    | 0.34    | 0.13        | 0.15    | 0.52    |
| Jari River             |        |          |         |         |         |             |         |         |         |         |         |         |         |         |         |         |
| Gussevia arilla        | 0.55  | 0.01     | 0.60    | 0.005   | 0.21    | 0.37        | 0.36    | 0.12    | 0.04    | 0.84    | 0.38    | 0.10    | 0.36    | 0.11    |
| Gussevia longihaptor   | 0.61  | 0.004    | 0.52    | 0.01    | 0.30    | 0.19        | 0.35    | 0.13    | 0.07    | 0.76    | -0.009  | 0.97    |
| Gussevia tucunarense   | 0.51  | 0.02     | 0.39    | 0.09    | 0.47    | 0.03        | 0.41    | 0.07    | 0.07    | 0.75    |
| Gussevia undulata      | 0.31  | 0.18     | -0.05   | 0.86    | 0.17    | 0.48        | 0.15    | 0.52    |
| Sciadicleithrum ergensi| 0.69  | 0.004    | 0.29    | 0.21    | 0.05    | 0.82        |         |         |         |         |         |         |
| Sciadicleithrum umbilicum| 0.43 | 0.06     | 0.34    | 0.13    |         |             |         |         |         |         |         |         |
| Sciadicleithrum uncinatum| 0.15 | 0.52     |         |         |         |             |         |         |         |         |         |         |
River had a similarity of 87.5%, and this similar composition can be expected for a same species of similar environment (Oliveira et al., 2017).

The Cichla species includes typically sedentary fish species, whose movements are restricted to a few kilometers (Hoeinghaus et al., 2003). The composition and structure of the monogenean communities of C. monoculus, a widely-distributed fish in the Amazon region (Kullander & Ferreira, 2006; Willis et al., 2007), from two rivers 320 km apart, was compared. Cohen et al. (2013) listed eight species of monogeneans described for Cichla species, and we found these same species in C. monoculus from the Jari River, and only seven in hosts from the Tapajós River, which had T. cichlae. These absence of T. cichlae from the Tapajós River may be due to the low sampling of fish. In comparison with other studies, the species richness of monogeneans found here was greater than that registered for Cichla kelberi Kullander & Ferreira, 2006 from the Paraná River basin (Takemoto et al., 2009), Rosana Reservoir (Yamada & Takemoto, 2013) and Laje Reservoir (Yamada & Takemoto, 2011), as well as for Cichla piquiti Kullander & Ferreira, 2006 from the Itaipu Reservoir (Yamada & Takemoto, 2011). However, all these studies were carried out with species of Cichla introduced into such watersheds, a condition that certainly influenced the diversity of the monogeneans of these hosts, because the parasites loss can occur after introduction into a new environment (Lacerda et al., 2013).

The present study, besides extending the knowledge of the geographic distribution of monogeneans for species of Cichla, also provides comparative data on species richness, prevalence, mean intensity and mean abundance, which are of great importance in the understanding in parasite-host-environment interaction. The Tapajós and Jari rivers are large tributaries of the Amazon River system and have their own environmental characteristics, due to the location of their mouths, and thus suffer differing influences from the waters of the Amazon River, due to the occurrence of daily tides in the Jari River (Abreu & Cunha, 2015). Daily tides of Amazon River can directly affect the local biota of its tributaries (Junk, 2013). The similar species richness and structure of the monogenean communities from the two populations of C. monoculus suggest the wide distribution of parasites of this host throughout its area of occurrence in the Amazonian biome. However, the community structure of these parasites revealed different levels of prevalence and abundance, as well as the dominance of G. arilla in C. monoculus from the Tapajós River and dominance of S. umbilicum in hosts from the Jari River. Similarly, differences in the structure of the parasite communities related to the characteristics of each environment have been reported for different host species (Paulin & Morand, 1999; Francová & Ondráčková, 2011; Santana-Pineros et al., 2012; Marcogliese et al., 2016). Levels of parasitism for the same host can vary spatially, with higher values at sites where hosts are more abundant and environmental conditions are more suitable for development, transmission and survival during the free-living and infectious stages of the parasites (Lagruè & Poulin, 2015). Possibly, differences in environmental characteristics influenced the levels of parasitism in C. monoculus, because the prevalence of G. arilla and G. tucunarense was greater in hosts from the Tapajós River, while the
prevalence of *G. longihaptor* was greater in hosts from the Jari River. The mean intensity of *G. arilia, G. tucunarensis*, *G. undulata, S. ergensi* and *S. umbilicum* was greater in fish from the Jari River, as was the abundance of *G. longihaptor, G. undulata, S. ergensi*, *S. umbilicum* and *S. uncinatum*.

In *C. monocus* from the Tapajós River there was a predominance of hosts infested by five to six species of monogeneans, while in fish from the Jari River there was a predominance of hosts with four to eight species. Such differences can be related to the low abundance and mean intensity of some species of monogeneans in the gills of hosts from the Tapajós River, resulting in greater micro-habitat availability for the establishment of different monogenean infracommunities. Competition among species of parasites can be verified by the negative correlation between the abundance of the same (Šimková *et al.*, 2000). However, only significant positive correlations were found between the abundance of the monogenean species from the Tapajós and Jari rivers, suggesting that there no competition among species, which can facilitate the coexistence of these parasites in the gills (Desdevives *et al.*, 2000). Oliveira & Tavares-Dias (2016) also reported similar results for *Piaractus brachypomus* parasitized by *Anacanthorus spathulatus, Mymarothecium viatorum* and *Notozothecium janauachensis*.

In summary, this study increased the knowledge on the diversity of monogeneans in *C. monocus* from the Amazon basin, and showed a moderate parasitism in the host population, which had an aggregate dispersion of parasites. The *C. monocus* population of both localities shared the mostly of the species of monogeneans, as expected. However, were found differences in the levels of both localities shared the mostly of the species of monogeneans in *C. monocus* from these two Amazonian basins.

**Conflict of Interest**
Authors state no conflict of interest.

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