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Original paper

Diversity and community ecology of metazoan parasites in *Tetragonopterus argenteus* Cuvier, 1816 (Characiformes, Characidae) from Jaguaribe River basin in Brazil

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ABSTRACT. The present study aims to inventory the metazoan parasites of *Tetragonopterus argenteus* from the Lima Campos weir, municipality of Icó, Ceará, Brazil and to analyze the influence of the host size and sex on the prevalence and parasitic abundance. A total of 359 metazoan parasites specimens were collected from 54 specimens of *T. argenteus*, presenting a mean intensity of 7.04 parasites/fish and prevalence of 94%. A richness of 10 parasite taxa were recorded, taxonomically classified into the following groups: Monogenea (n=1), Digenea (n=2) and Nematoda (n=7). The parasite community of *T. argenteus* was composed of helminth species with low prevalence, low mean intensity, low mean abundance, low dominance and low diversity, predominance of endoparasites of the phylum Nematoda. As for the importance value, six species were considered secondary and showed an aggregated dispersion pattern. The host size influenced significantly the abundance of *Creptrotrema* sp. and the prevalence of *Procamallanus* (S*pirocamallanus*) *hilarii*. The results present new reports of parasites have been recorded for this host, thus expanding the ecological interactions between parasites and Characiformes fish and contributing to the knowledge of the freshwater biodiversity from Brazilian Caatinga domain.

Keywords: Caatinga domain, freshwater fish, helminths, Neotropical region, Tetragonopteriae, Brazil

Introduction

Fish constitute the most diverse group of vertebrates with around 35,000 species with a wide variety of body shapes, coloration and life strategies, resulting from 500 million years of evolution [1]. The Neotropical region has the highest diversity of freshwater fish, with around 5,400 species [2] and with future projections for up to 9,000 species [3]. Of this diversity, 2,587 valid species were recorded in Brazilian freshwater ecosystems, distributed in 517 genera, 39 families and nine orders [3,4].

Among the fish genera that occur in the Neotropical region, *Tetragonopterus* Cuvier, 1816 (Characiformes, Characidae) is widely distributed in the main river basins of South America, occurring additionally in the main rivers of the Brazilian Northeast [5]. *Tetragonopterus argenteus* Cuvier, 1816 popularly known as "Piaba do olhão or Sauá", shelters specimens with about 11.2 cm, with sexual dimorphism and opportunistic herbivorous feeding behavior. This species has economic importance for being used as bait for fishing, as well as in human food [6–8].

Studies on the fish parasite community expand the knowledge about the parasite-host-environment relationship and the strategies used by different groups of metazoan parasites [9–13], as well as the diversity of these helminths in the ecosystems [12,13]. The parasites are able to directly influence the population structure by causing fish mortality, or indirectly by reducing the growth and feeding rate, reproduction, and also the swimming speed, increasing the risk of predation [2,14,15]. Thus, the present study aimed to inventory the metazoan parasites of *T. argenteus* from the Lima Campos weir, municipality of Icó, Ceará state (Brazil), and to analyze the influence of the host size and sex on the prevalence and parasitic abundance.

Materials and Methods

Fifty-four specimens of *T. argenteus* were captured between September 2019 and March 2020 in the Lima Campos weir (0°02′34,4″S, 55°05′52,18″W), Upper Jaguaribe River basin, municipality of Icó, Ceará state, Brazil. Individuals were measured (standard length, SL to the nearest 0.1 mm), weighed (to the nearest 0.1 g), and dissected for sex identification (i.e. macroscopic examination of gonad features). After, the nostrils, gills and gastrointestinal tract and viscera of each fish were examined with aid of stereomicroscope and the recovered parasites were fixed with 70% ethyl alcohol. The collections were authorized by the Biodiversity Authorization and Information System of the Brazilian government (SISBIO #61328-1) and all animal procedures were performed in full compliance with the Ethics Committee for Animal Experimentation (CEUA # 00165/2018.1). The collection, preservation and preparation of the parasites were conducted based on the methodology of Eiras et al. [16]. The taxonomic identification of the host was performed using Silva et al. [5], Silva et al. [7], Cohen et al. [17], Moravec [18] and Thatcher [19].

Statistical analyzes were performed at the component community level (i.e., all helminths of all fish collected parasite) and the ecological descriptors of prevalence, mean intensity and mean abundance were calculated according to Bush et al. [20].

The Dispersion Index (DI) was calculated to verify the distribution pattern of each parasite species, where DI=1: indicates a random distribution; DI<1: indicates uniform or regular arrangement and DI>1: indicates an aggregated distribution [21,22]. Spearman's correlation coefficient (*rs*) was used to determine possible correlations of parasite abundance with length and Pearson's correlation coefficient (r) to verify the correlation between parasite prevalence and standard host length classes [23]. The Mann-Whitney "U" test was used to determine the effect of host sex on the abundance of each parasite species [24]. The influence of host sex in relation to parasite prevalence was verified through the Chi-square test (χ^2), using a paired contingency table 2x2 [23].

The dominance of the components of the parasite community was determined by calculating the dominance frequency (number of specimens of one species/total number of specimens of all species in the community) [25]. The parasite diversity was determined for the component community by the Shannon-Wiener (H') index, which consider the weight equal to the rare and abundant species, and the Berger-Parker (d) index, which assesses uniformity [25]. The importance value of Caswell [26] and Hanski [27] was used to verify the degree of importance of each species in the parasitic community (i.e., species whose prevalence was higher than 66.66% were considered as central; between 33.33 and 66.66% as secondary; and less than 33.33% as satellite). The statistical analyzes were performed using the Statistica software package version 7.1. The significance level adopted for statistical analysis was $P \leq 0.05$.

Results

Fifty-four specimens of *T. argenteus* with average weight of 9.76 g (3.17–21.31 g) and average length of 6.17 cm (3.1–9.2 cm) were analyzed. Of the examined specimens, 51 (94%) were parasitized by at least one metazoan parasite species and three hosts (6%) were not parasitized by any species.

A total of 359 metazoans were recovered, with a mean intensity of 7.04 parasites/fish analyzed. A richness of 10 parasite taxa were recorded, taxonomically classified into the following groups: Monogenea (n=1), Digenea (n=2) and Nematoda (n=7). The phylum Nematoda was the most representative taxonomic group in terms of species richness and abundance, with emphasis on larvae of *Spiroxys* sp. (n=124); the other species were *Procamallanus* (*Spirocamallanus*) *hilarii* (n=58); *Procamallanus* (*Spirocamallanus*) *inopinatus* (n=8); *Procamallanus* (*Spirocamallanus*) *saofranciscensis* (n=2); *Procamallanus* (*Spirocamallanus*) *pereirai* (n=3); *Procamallanus* (*Spirocamallanus*) sp. (n=1) and *Contracaecum* sp. (n=2). The digenean specimens *Creptotrema* sp. (n=107) and the metacercariae of *Clinostomum* sp. (n=1) were parasitizing the intestine and gills, respectively, and one monogenean species *Ancistrohaptor* sp. (n=53) in the nostril. The parasite community of *T. argenteus* showed low prevalence, mean intensity and mean abundance. The Monogenea *Ancistrohaptor* sp. was the most prevalent species (57%), followed by *P.* (*S.*)

Table 1. Metazoan parasite community of *Tetragonopterus argenteus* collected in the Lima Campos weir, Jaguaribe basin, Ceará state, Brazil. N: Number of parasites collected, P%: Prevalence, MA: Mean abundance, MI: Mean intensity, SE: Standard error, DS: Developmental stage, SI: Site of infection/infestation, IV: importance value, Ce = Central species; Se = Secondary species; Sa = Satellite species)

Parasites	N	P (%)	MI ± SE	MA ± SE	DS	SI	IV
Monogenea							
Ancistrohaptor sp.	53	57	1.70±0.16	0.98±0.21	Adult	Nostrils	Se
Digenea							
Creptotrema sp.	107	33	5.94±0.58	1.98±1.34	Adult	Intestine	Se
Clinostomum sp.	1	2	1	0.01±0.09	Metacercariae	Gills	Sa
Nematoda							
Procamallanus (*Spirocamallanus*) *hilarii*	58	55	1.93±0.21	1,07±0.18	Adult	Intestine	Se
Procamallanus (*Spirocamallanus*) *inopinatus*	8	11	1.33±0.33	0.15±0.07	Adult	Intestine	Sa
Procamallanus (Spirocamallanus) *pereirai*	3	5	1	0.05±0.03	Larvae	Mesentery	Sa
Procamallanus (*Spirocamallanus*) *saofranciscencis*	2	2	2	0.03±0.04	Adult	Intestine	Sa
Procamallanus (*Spirocamallanus*) sp.	1	2	1	0.01±0.09	Adult	Intestine	Sa
Spiroxys sp.	124	48	4.76±0.91	2.29±0.54	Larvae	Intestine, mesentery and stomach	Se
Contracaecum sp.	2	4	1	0.03±0.04	Larvae	Mesentery	Sa

Table 2. Spearman's rank correlation coefficient (rs) and Pearson's correlation coefficient (r) to assess the relationship of the host length and abundance and prevalence of parasites, respectively, of parasite community of *Tetragonopterus argenteus* collected in the Lima Campos weir, Jaguaribe basin, Ceará state, Brazil

Parasites	rs	*p*	r	*p*
Monogenea				
Ancistrohaptor sp.	0.1737	0.2091	0.3851	0.3935
Digenea				
Creptotrema sp.	0.3626	0.0070*	0.6444	0.1181
Clinostomum sp.	0.1881	0.1731	0.4082	0.3632
Nematoda				
Procamallanus (*Spirocamallanus*) *hilarii*	-0.1668	0.2279	-0.8156	0.0253*
Procamallanus (*Spirocamallanus*) *inopinatus*	0.1159	0.4039	0.4925	0.2614
Procamallanus (*Spirocamallanus*) *pereirai*	0.2325	0.0906	-0.2505	0.5880
Procamallanus (*Spirocamallanus*) *saofranciscencis*	-2.2351	0.0869	-0.6124	0.1437
Procamallanus (*Spirocamallanus*) sp.	0.0188	0.8926	0.4082	0.3632
Spiroxys sp.	0.8926	0.2573	0.1840	0.6930
Contracaecum sp.	0.1477	0.2865	0.1581	0.7349

**p*. Significance level (* Significant value)

hilarii (55%). *Creptotrema* sp. showed the highest mean intensity of infection (5.94 ± 0.58) and *Spiroxys* sp. was the most abundant (2.29 ± 0.54) (Tab. 1).

The nematode *Spiroxys* sp. showed the highest number of all parasite specimens recovered, representing around of 34% of all parasites collected, followed by *Creptotrema* sp. (30%), *P.* (*S.*) *hilarii* (16%) and *Ancistrohaptor* sp. (15%). *Procamallanus* (*S.*) *inopinatus*, *P.* (*S.*) *pereirai*, *P.* (*S.*) *saofranciscencis*, *Procamallanus* (*S.*) sp., *Contracaecum* sp. and *Clinostomum* sp. showed a smaller number of specimens (2.0%, 0.8%, 0.5% 0.2%, 0.2%, 0.2%, respectively).

According to the importance value of the parasitic community of *T. argenteus*, the helminths *Spiroxys* sp., *Creptotrema* sp., *Ancistrohaptor* sp. and *P.* (*S.*) *hilarii* were classified as secondary species, and *P.* (*S.*) *inopinatus*, *P.* (*S.*) *pereirai*, *P.* (*S.*) *saofranciscencis*, *P.* (*S.*) sp., *Contracaecum* sp., and *Clinostomum* sp. were classified as satellite species (Tab. 1).

The abundance of *Creptotrema* sp. showed a positive and significant correlation with the length of *T. argenteus* (rs=0.363; p=0.007). There was no correlation between the host length and the parasite abundance in the other species (Tab. 2). The prevalence of *P.* (*S.*) *hilarii* (r=-0.813, p=0.025) showed a negative and significant correlation with the length of the host (Tab. 2). There were no significant differences in the prevalence and parasitic burden between the sexes of the hosts (Tab. 3). Considering the spatial distribution pattern of the parasitic community of *T. argenteus*, *Ancistrohaptor* sp., *Creptotrema* sp., *P.* (S.) *hilarii*, *P.* (*S.*) *inopinatus*, *P.* (*S.*) *saofranciscencis* and *Spiroxys* sp., showed an aggregated dispersion pattern. The other parasites species showed random dispersion (Tab. 4). The parasite component community showed H'=1.55 of the Shannon-Wiener diversity index and d=0.34 the Berger-Parker uniformity index and evenness.

Discussion

Metazoan parasites of fish belong to different taxonomic groups and are acquired in different ways, establishing themselves outside or in the different internal organs of their hosts [28]. The composition of the parasitic communities is the result, among other factors, of interactions between evolutionary history and ecological characteristics of the fish [29]. The component community of

Table 3. Mann-Whitney "U" test and Chi-square test (χ^2) used to verify the influence of sex of *Tetragonopterus argenteus* on parasite abundance and prevalence, respectively. collected in the Lima Campos weir, Jaguaribe basin, Ceará state, Brazil

Parasites	Z(U)	*p*	χ^2	*p*
Monogenea				
Ancistrohaptor sp.	0.8876	0.3748	1,2080	0.2717
Digenea				
Creptotrema sp.	1,0053	0.3148	0.0200	0.8881
Nematoda				
Procamallanus (*Spirocamallanus*) *hilarii*	0.1540	0.8776	0.1020	0.7500
Procamallanus (*Spirocamallanus*) *inopinatus*	0.5525	0.5806	2,1190	0.1455
Procamallanus (*Spirocamallanus*) *pereirai*	0.0272	0.09783	0.0050	0.9449
Spiroxys sp.	0.1540	0.8776	0.0070	0.9327

**p*. Significance level (* Significant value)

metazoan parasites in *T. argenteus* from the Lima Campos weir, consisted of a richness of 10 parasite taxa that were recorded, predominantly of endoparasites of the phylum Nematoda. These results are probably associated to opportunistic feeding behavior of this host fish species. Furthermore, this study presented a rich parasite community that had not yet been recorded for this host and in Caatinga domain.

In *T. argenteus*, only one species of monogenean of the genus *Ancistrohaptor* was present, this taxon presents a high specificity for fish of the genus *Triportheus*, being reported in the gills of *Triportheus angulatus* (Spix and Agassiz, 1829), *Triportheus albus* (Cope, 1872), *Triportheus elongatus* (Günther, 1864) and *Triportheus rotundatus*

Table 4. Distribution pattern of metazoan parasites of *Tetragonopterus argenteus* collected in the Lima Campos weir, Jaguaribe basin, Ceará state, Brazil

Parasites		s^2	DI	Dispersion type
Monogenea				
Ancistrohaptor sp.	0.981	1.452	1.480	Aggregate
Digenea				
Creptotrema sp.	1.981	18.51	9.344	Aggregate
Clinostomum sp.	0.185	0.185	1.000	Random
Nematoda				
Procamallanus (*Spirocamallanus*) *hilarii*	1.074	1.768	1.646	Aggregate
Procamallanus (*Spirocamallanus*) *inopinatus*	0.148	0.242	1.635	Aggregate
Procamallanus (*Spirocamallanus*) *pereirai*	0.055	0.053	1.000	Aggregate
Procamallanus (*Spirocamallanus*) *saofranciscencis*	0.037	0.074	2.000	Aggregate
Procamallanus (*Spirocamallanus*) sp.	0.016	0.016	1.000	Random
Spiroxys sp.	2.296	15.91	6.929	Aggregate
Contracaecum sp.	0.037	0.036	1.000	Random

Mean, s^2: Variance, DI: Dispersion Index and dispersion type

(Jardine, 1841) [17,30–33]. *Ancistrohaptor* sp. was the most prevalent species (57%), which can be explained by the fact that monogeneans have a direct life cycle. This high prevalence of helminths belonging to the Monogenea class was also verified in the study by Reis et al. [34]. This monogenean species is probably a new species parasitizing the nostrils of *T. argenteus* and in a new geographic region.

To date, the following species of the genus *Creptotrema* have been recorded parasitizing Characiformes, these species being: *Creptotrema schubarti* Franceschini, Aguiar, Zago, Yamada and Ebert, 2021 in *Characidium schubarti* Travassos, 1955 from the Upper Paraná basin, São Paulo [35]; *Creptotrema lynchi* Brooks, 1976 in *Leporinus obtusidens* (Valenciennes, 1847) in the Upper Paraná River, São Paulo [36–38] and Lake Guaíba, Rio Grande do Sul [39]; *Creptotrema* sp. in *Tetragonopterus chalceus* Spix and Agassiz, 1829 from the Três Marias Reservoir, Upper São Francisco River, Minas Gerais state [40]; and *Creptotrema sucumbiosa* (Curran, 2008) and *Creptotrema dissimilis* (Freitas, 1940) in *T. argenteus* of Aquarico River, Ecuador, and Miranda River, Mato Grosso state, Brazil, respectively [41,42]. In the present study, *Creptotrema* sp. in *T. argenteus* represents a new geographic record.

Clinostomum Leidy, 1856, is a digenean belonging to the family Clinostomidae, in which it has zoonotic potential, occurring in freshwater and estuarine ecosystems worldwide [43,44]. According to Tavares-Dias et al. [45] approximately 60 species of freshwater fish from Brazil act as intermediate hosts for *Clinostomum* metacercariae, including 20 species of Characiformes, distributed in the following genera: *Acestrorhynchus* Eigenmann and Kennedy, 1903; *Astyanax* Baird and Girard, 1854; *Hoplerythrinus* Gill, 1896; *Hoplias* Gill, 1903; *Leporinus* Agassiz, 1829; *Oligosarcus* Günther, 1864; *Piaractus* Eigenmann, 1903, *Pygocentrus* Müller and Troschel, 1844; *Salminus* Agassiz, 1829, *Serrasalmus* Lacépède, 1803 and *Tetragonopterus*. To date, there was no records of *Clinostomum* metacercariae for *T. argenteus*. Thus, the present study expands the list of intermediate hosts for this helminth.

Nematodes are endoparasites of fish which may be present from the larval stage to the adult form. These helminths have a great diversity in fish from South America, with approximately 303 known species, of which 143 species have been reported in freshwater fish from Brazil [46,47]. This endoparasite group was dominant and richest of parasitic fauna in *T. argenteus*, such differences may be probably related to the feeding habit of the host. We observed that this host species was feeding on aquatic insects, this result indicate that *T. argenteus* may act as intermediate hosts in the life cycle of these parasites.

Specimens of *P.* (*S.*) *hilarii* (Nematoda; Camallanidae) found in the present study are morphologically similar to those reported by Gallas et al. [48], who detailed the morphology of this species parasitizing *Psalidodon fasciatus* (Cuvier, 1819) and *Astyanax jacuhiensis* (Cope, 1894) from Lake Guaíba, in Rio Grande do Sul state, Brazil. In Brazil, *P.* (*S.*) *hilarii* were recorded in several Characiformes, among which: *Astyanax bimaculatus* (Linnaeus, 1758) [49]; *A. jacuhiensis* [48]; *Astyanax parahybae* (Eigenmann, 1908) [49]; *Hoplias malabaricus* (Bloch, 1794) [50]; *P. fasciatus* [48]; *Salminus hilarii* (Valenciennes, 1850) [52]; *Triportheus nematurus* (Kner, 1858) [51]. In this work, *P.* (*S.*) *hilarii* is reported for the first time in the host and in the Lima Campos weir, municipality of Icó, Ceará state, Brazil.

According to Neves et al. [52] *P.* (*S.*) *inopinatus* in the adult stage is found parasitizing a great diversity of Brazilian fish, including several Characiformes, belonging to the genera: *Acestrorhynchus* Eigenmann and Kennedy, 1903; *Astyanax* Baird and Girard, 1854; *Brycon* Müller and Troschel, 1844; *Bryconops* Kner, 1858; *Colossoma* Eigenmann and Kennedy, 1903; *Cynopotamus* Valenciennes, 1850; *Galeocharax* Fowler, 1910; *Hemibrycon* Günther, 1864; *Hoplerythrinus* Gill, 1896; *Hoplias* Gill, 1903; *Hyphessobrycon Durbin*, 1908; *Leporellus* Lütken, 1875; *Leporinus* Agassiz, 1829; *Myloplus* Gill, 1896; *Mylossoma* Eigenmann and Kennedy, 1903; *Prochilodus* Agassiz, 1829; *Pygocentrus* Müller and Troschel, 1844; *Rhaphiodon* Agassiz, 1829; *Salminus* Agassiz, 1829; *Schizodon* Agassiz, 1829; *Semaprochilodus* Fowler, 1941; *Serrasalmus* Lacepède, 1803 and *Triportheus* Cope, 1872. These occurrences corroborate its low parasite specificity and wide geographic distribution, with one more host being reported for this helminth and a new geographic record.

Moreira et al. [53] described *P.* (*S.*) *saofranciscencis* parasitizing *Tetragonopterus chalceus* (Spix and Agassiz, 1829) and *Astyanax lacustris* (Lütken, 1875), differing from *P. (S.) inopinatus* by the following characteristics: presence of tooth-like formations at the bottom of the buccal capsule, due to the height/width ratio of the buccal capsule and the presence of four projections similar to retractable teeth at the mouth opening. *Procamallanus* (*S.*) *saofranciscensis* was reported in seven species of Characiformes from Brazil: *A. lacustris* and *T. chalceus* [53]; *T. angulatus*, *Acestrorhynchus lacustris* (Lütken, 1875), *Leporinus piau* (Fowler, 1941), *P. fasciatus* and *T. guentheri* (Garman, 1890) [54]. This is the first record for *T. argenteus*, thus increasing the number of hosts and it is also a new location.

Procamallanus (*S.*) *pereirai* specimens have been reported in Brazilian fish belonging to the order Perciformes: *Paralonchurus brasiliensis* (Steindachner, 1875), *Stellifer brasiliensis* (Schultz, 1945), *Nebris microps* Cuvier, 1830 and *Menticirrhus americanus* (Linnaeus, 1758), collected in Rio de Janeiro, Brazil [55]. To date, there was no record of this nematode species in Characiformes, this was the first record of *P.* (*S.*) *pereirai* for *T. argenteus*, for the region under study and also for the Characiformes.

Adult nematodes of the genus *Spiroxys* sp. are parasites mainly of freshwater turtles [56]. According to Moravec [18], copepods act as intermediate hosts, where the infectious larvae of the third stage develop. Amphibians, mollusks, dragonflies and freshwater fish act as paratenic hosts for nematodes of this genus [57,58]. Several occurrences of *Spiroxys* sp. have been reported in Brazilian Characiformes: *Astyanax altiparanae* (Garutti and Britski, 2000) [59]; *P. fasciatus* [60]; *Pygocentrus piraya* (Cuvier, 1819) and *Serrasalmus brandtii* (Lütken, 1875) [59]; *Salminus hilarii* (Valenciennes, 1850) [61]; *T. chalceus* and *T. guentheri* [62]; *Hoplias malabaricus* (Bloch, 1794); *Hoplosternum littorale* (Hancock, 1828) and *A. bimaculatus* [63]. This is the first record for *T. argenteus*, expanding the list of paratenic hosts and a new locality.

According to Pinheiro et al. [64], *Contracaecum* Railliet and Henry, 1912 has a wide geographic distribution, having been found parasitizing more than 70 species of Brazilian fish, occurring in several Characiformes: *P. fasciatus* [60]; *Hoplerythrinus unitaeniatus* (Agassiz, 1829) [67]; *H. malabaricus* [65,50]; *Hemibrycon surinamensis* (Géry, 1962) [66]; *Piaractus mesopotamicus* (Holmberg, 1887) [67]; *T. angulatus* [68], in several species of the genus *Astyanax* [69–72]; and in *T. argenteus* [70]. These occurrences have been demonstrating low specificity regarding its intermediate host [18]. This study is a new locality and reinforces the role of *T. argenteus* as an intermediate host for this helminth.

In this work, it was possible to verify the presence of parasitic at different stages of development. A similar result was also observed in the study by Hoshino et al. [66]. The presence of larvae indicates that the fish is a prey with an intermediate position in the food web, acting as an intermediate or paratenic host for one or several parasite species [73,74]. Thus, parasites in larvae stage reported in the present study indicate that *T. argenteus* acts as an intermediate host for *P.* (*S.*) *pereirai* and *Contracaecum* sp. and as a paratenic for *Spiroxys* sp.

According to Bush and Holmes [75] communities are formed by a core of central species, in which they interact strongly to achieve the balance proposed by Caswell [26]. The central species, in turn, are surrounded by a set of secondary and satellite species, which work in the opposite direction towards the fall of this balance [76]. The parasitic community of *T. argenteus* does not dominant species (i.e., central species), a similar result was found in *T. angulatus* fom Solimões River, Amazonas state, Brazil by Moreira et al. [31]. Parasite community dominated by satellites species, as in the present study, may indicate a low availability of intermediate hosts, a low rate of transmission and life cycle success [76].

In *T. argenteus*, regarding the host-parasite relationship, there was a positive correlation between the host standard length and the abundance of the digenean *Creptotrema* sp. Probably, this fact can be explained by host size being related to age or by larger host harboring more parasites, there is also a process of accumulation of the parasites throughout the life of the host [77–79]. In contrast, a negative correlation was observed between the host standard length and the prevalence of *P.* (*S.*) *hilarii*, demonstrating that the prevalence decreased with increasing fish size. According to Carvalho et al. [80], older fish may develop an immune response, which may lead to a decrease in the accumulation of parasites.

According to Esch et al. [81] the sex of the host can influence the levels of parasitism, due to behavioral and physiological differences. In this study, although *T. argenteus* presents sexual dimorphism [7], the sex of this host did not influence on the levels of parasitism, which was probably a consequence of the male and female specimens of *T. argenteus* playing the same ecological niche, and have the same feeding habit, corroborating with Oliveira and Bennemann [82] in which they showed that fish exposed during the same period of time, present behavioral similarity.

The metazoans analyzed in the present study showed low prevalence, which may be associated with the aggregate distribution of the parasites. Similar findings were reported by Reis et al. [34], Amarante et al. [83] and Lima et al. [84], and this distribution pattern being common in several species of freshwater fish, in which it may be associated with the genetic variability of the host population, decreased interspecific competition between parasites, decreased damage to the host and other environmental factors [78,85,86].

The parasite community of *T. argenteus* was composed of helminth species with low prevalence, low mean intensity, low mean abundance, low dominance and low diversity, predominance of endoparasites of the phylum Nematoda. The host species under study still has gaps in the literature about the parasites it harbors. To date, there are no studies that describe the structure of the parasite community of *T. argenteus*, in addition new reports of parasites have been recorded for this host, thus expanding the ecological interactions between parasites and Characiformes fish and contributing to the knowledge of the freshwater biodiversity from Caatinga domain.

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