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ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

BIODIVERSITY OF FISH PARASITES FROM GUANDU RIVER, SOUTHEASTERN BRAZIL: AN ECOLOGICAL APPROACH

BIODIVERSIDAD DE LOS PARÁSITOS DE PECES DE RÍO GUANDU, SURESTE DE BRASIL: UNA APROXIMACIÓN ECOLÓGICA

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Abstract

Here, we performed a quantitative analysis of the parasite communities in 21 species of fish from Guandu River, Brazil; we evaluated the effects of some host traits (body size, social behavior, fish's habitat, trophic category and ability to migration) on the diversity of their communities of metazoan parasites. To measure quantitative diversity, we used parasite species richness, as well as the average taxonomic distinctness of the assemblage and its variance. The parasite species richness, the taxonomic distinctness and the variance were unaffected by the number of host individuals examined per species. Fish body length proved to be the main predictor of parasite species richness, although it did not correlate with parasite taxonomic distinctiveness. The mains host features associated with the taxonomic diversity of parasites were schooling behavior and omnivores trophic category. Parasite communities found in fish from Guandu River isolationist communities.

Key words: Biodiversity- Brazil- ecology parasite- fishes- Guandu River- parasites.

Resumen

En el presente trabajo, se realiza un análisis comparativo de las comunidades de parásitos de 21 especies de peces en el río Guandu, Brasil y se evaluó el efecto de algunas de las características del huésped (tamaño corporal, comportamiento social, hábitat de los peces, categoría trófica y capacidad de migrar) en la diversidad de sus comunidades de parásitos metazoarios. Como una medida de diversidad, hemos utilizado la riqueza de especies de parásitos y la diversidad taxonómica. La riqueza de especies de parásitos y la diversidad taxonómica no se vieron afectados por el número de los especímenes examinados por especie. El tamaño del cuerpo de los peces mostró una correlación significativa con la riqueza de especies de parásitos, aunque no hay correlación con la diversidad taxonómica de los parásitos. Las principales características asociadas a la diversidad taxonómica de los parásitos son la formación de cardúmenes y la categoría trófica omnívora. Las comunidades de parásitos de peces en el río Guandu presentaron comunidades parasitarias aisladas.

Palabras clave: Biodiversidad- Brasil- ecología parasitaria- parásitos- peces - río Guandu.

INTRODUCTION

Parasite communities are playing an increasingly important role as models for the study of biodiversity and biogeography (Poulin & Morand, 2000). Given the integral roles played by parasites in natural ecosystems, identifying hotspots of high parasite diversity, as well as areas of relatively low parasite diversity, is crucial for a complete understanding of the functioning of the biosphere. Currently, the biodiversity of marine and freshwater ecosystems of Latin America is threatened, mainly by environmental problems resulting from the destruction and degradation of the ecosystems. In this context, parasite biodiversity can be very important because parasitism plays key roles in ecosystems, regulating the abundance or density of host populations, stabilize food webs and structuring animal communities (Luque & Poulin, 2007).

Takemoto *et al*. (2005) performed the first study relating the different features of host species and the parasite species richness in freshwater fishes from Neotropical Region. In fish, for instance, some previous studies have found that host body size is a good predictor of parasite species richness whereas others have found no effect of host size. The same is true for a range of other host features. It is therefore difficult to assess the relative importance of different host traits for the evolution of parasite diversity in general (Luque *et al*., 2004; Luque & Poulin, 2008).

In the present study, we examine the relationship between different features of host species and the diversity of metazoan parasite communities across species of fish hosts from Guandu River (Fig. 1) in function of the strategic importance of this river, which is the main source of potable water in Rio de Janeiro, Brazil. The Guandu River supply water to 90% of population of City of Rio de Janeiro and although be a very impacted environment (Bizerril & Primo, 2001), it maintains an important level of biodiversity of fishes, and consequently, fish parasites (Azevedo *et al*., 2010). In addition, data about population and community and quantitative descriptors from the fish hosts are given herein.

MATERIAL AND METHODS

Between April 2003 to September 2009 were analyzed 786 specimens of fish, belonging to 21 species (Table 1) from the Guandu river, near the dam of water treatment station (WTS) (22°48'32"S, 43°37'35"W). The taxonomy of the fishes follows that of Reis *et al*. (2003). Parasites were collected from the body surface, gills, and body cavities, and viscera after examination under a stereoscopic microscope. Washings from gills and gut lumen were strained using a sieve (53 and 75 µm mesh size) to retain even the smallest parasites. Following Bush *et al.* (1997), prevalence, intensity and abundance mean were calculated for parasites of all fish species.

Pearson's correlation coefficient *r* was used to analyze the possible correlation between the host's total body length and the abundance of parasites, with previous logarithmic transformation Log (x+1) (Zar, 1999). The analysis included only parasite species with prevalence greater than 10% (Bush *et al*., 1990).

The following descriptors were calculated at the parasites infracommunity level: total prevalence, total intensity, total abundance, total species richness, endoparasite and ectoparasite species richness, Margalef's richness index (d), Brillouin's diversity index (*H*) (log 10 based), Pielou's evenness index (J`) and Berger-Parker dominance index. In addition the Bray-Curtis similarity index was calculated among infracommunities within host fish species (Magurran, 2004). These descriptors were used for all parasites with exception of myxozoans. Statistical significance level was established at $P<0.05$. All results were presented in tabular form (Tables 2 and 3). The relative abundance of metazoan parasites was calculated at the level of infracommunities for all species of fish that had more than three species of parasites. The results were presented in graphical form (Figs. 2 and 3).

For each fish species, the average taxonomic distinctness ($\Delta+$) and variance in taxonomic distinctness ($\Lambda+$) of the parasite component community were computed, following the procedures and taxonomies used by Luque & Poulin (2008). The effect of host length on taxonomic distinctness, on variance and on total richness were evaluated using the Pearson correlation coefficient on logarithmic transformed data. The Student`s *t* test or ANOVA test, depending of the number of variables with previous transformation, was used to verify the influence of the followings variables in the taxonomic distinctness and variance in taxonomic distinctness: (1) whether the fish species forms schools or not, with species adopting schooling only in some parts of the year (e.g. during the reproductive period) classified as schooling; (2) whether the fish's habitat is benthic, benthopelagic or demersal; (3) the trophic category, where the fish species were distributed into four categories: detritivores, herbivores, omnivores or carnivores and (4) whether species accomplish or not migration, being classificated as potamodromous or diadromous. Data were obtained from Fishbase (Froese & Pauly, 2010). Table 4 showed the entire data set of host species included in the analyses.

The present study follows the classification and systematic arrangements used by Azevedo *et al.* (2010). Parasite species names follow those provided in the most recent taxonomic literature. Species of fishes are arranged in alphabetical sequence and valid names are adopted from Froese & Pauly (2010).

Figure 1. Map of the Guandu River and the area of collection (circle) near to the dam of water treatment station (WTS) (22°48'32" S, 43°37'35" W).

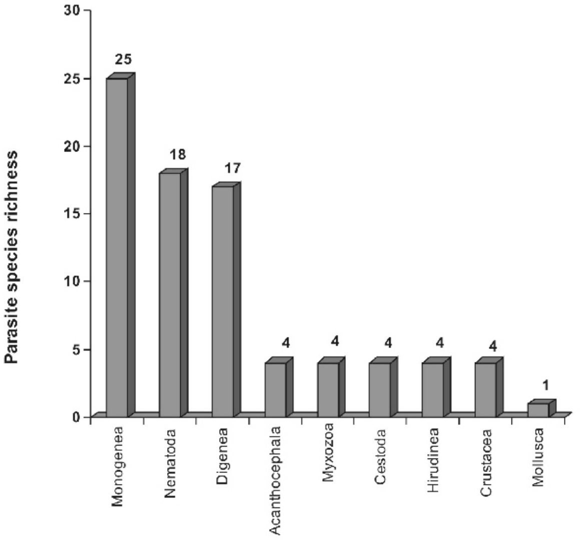

Figure 2. Species richness of fish parasites according to zoological group reported in the Guandu River, State of Rio de Janeiro, between 2003 to 2009.

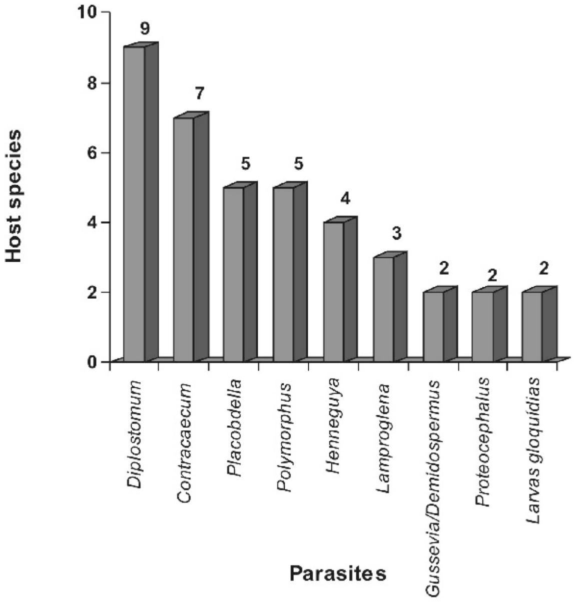

Figure 3. Distribution of parasite genera in fish's species collected from Guandu River, State of Rio de Janeiro, between 2003 to 2009.

RESULTS

A total of 786 specimens of fish was analyzed and were found 15.630 specimens of parasite belonging to 81 species. Nine groups of metazoan parasites were found: Acanthocephala, Cestoda, Crustacea, Digenea, Hirudinea, Mollusca, Monogenea Myxozoa and Nematoda. In these fish,

Table 1. Prevalence, mean abundance, mean intensity, site of infection / infestation of metazoan parasites from fish collected in the Guandu river, State of Rio de Janeiro, Brazil. (s = standard deviation, * parasites that had a positive correlation between abundance and its host's total length through Pearson's correlation coefficient *r*).

Parasite group	Parasite species	Prevalence (%)	Mean Abundance±s	Mean Intensity±s	Host species	Site of infection
Acanthocephala	*Polymorphus* sp. (cystacanth)	17.10	0.60±0.20	7.00±1.20	*Astronotus ocellatus*	Intestine
	Andracantha sp. (cystacanth)	16.60	0.23±0.02	1.40±0.11	*Centropomus undecimalis*	Liver, intestine
	Neoechinorhynchus paraguayensis	2.00	0.02±0.60	1.00±0.50	*Geophagus brasiliensis*	Intestine
	Polymorphus sp. (cystacanth)	2.00	0.02±0.60	1.00±0.60	*Geophagus brasiliensis*	Mesenteries
	Neoechinorhynchus sp.	3.00	0.03±1.18	1.00±0.18	*Gymnotus carapo*	Intestine
	Polymorphus sp. (cystacanth)	7.00	0.07±0.01	1.00±0.13	*Gymnotus carapo*	Intestine
	Polymorphus sp. (cystacanth)	10.0	3.80±0.41	0.40±0.04	*Oligosarcus hepsetus*	Intestine
	Polymorphus sp. (cystacanth)	6.66	0.13±0.02	2.00±0.28	*Rhamdia quelen*	Intestine
Cestoda	Trypanorhyncha gen. sp. (plerocercoid)	13.30	0.46±0.07	3.50±0.50	*Centropomus undecimalis*	Intestine
	Proteocephalus macrophallus	100.00	26.38±2.04	26.38±2.05	*Cichla ocellaris*	Intestine
	Proteocephalus sp.	13.00	0.33±0.04	1.67±0.21	*Gymnotus carapo*	Intestine
	Nomimoscolex sp.	7.50	0.10±0.01	1.33±0.13	*Pimelodus maculatus*	Intestine
Crustacea	*Lamproglena monodi*	5.70	0.05±0.10	1.00±0.50	*Astronotus ocellatus*	Gills
	Lamproglena monodi	8.00	0.08±0.01	1.00±0.14	*Cichla ocellaris*	Gills
	Ergasilus sp.	17.64	0.17±0.01	1.00±0.06	*Mugil liza*	Gills
	Naobranchia lizae	2.94	0.03±0.005	1.00±0.17	*Mugil liza*	Gills

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
	Lamproglena monodi	84.00	2.80±0.09	3.36±0.10	*Tilapia rendalii*	Gills
Digenea	*Clinostomum complanatum* (metacercariae)	25.00	0.60±0.03	2.20±0.13	*Astyanax bimaculatus*	Eyes, palate, intestine, muscle
	Clinostomum complanatum (metacercariae)	20.00	0.30±0.02	1.50±0.08	*Astyanax parahybae*	Eyes, tongue, palate, intestine, nasal cavity
	Acanthocollaritrema umbilicatum	56.70	5.73 ± 0.32	9.05 ± 0.51	*Centropomus undecimalis*	Intestine, stomach, pyloric diverticula
	Bucephalus sp.	6.70	0.23± 0.03	3.50±0.48	*Centropomus undecimalis*	Intestine
	Austrodiplostomum compactum (metacercariae)	6.70	0.26±0.03	4.00±0.52	*Centropomus undecimalis*	Eyes
	Austrodiplostomum compactum (metacercariae)	35.00	0.54±0.03	1.55±0.09	*Cichla ocellaris*	Eyes
	Austrodiplostomum compactum (metacercariae)	1.70	0.02±0.002	1.00±1.30	*Cyphocharax gilbert*	Eyes
	Sphincterodiplostomum musculosum (metacercariae)	40.00	4.50±0.13	11.40±0.38	*Cyphocharax gilbert*	Eyes
	Zonocotyloides haroltravassosi	6.70	0.20±0.02	2.80±0.24	*Cyphocharax gilbert*	Intestine
	Austrodiplostomum compactum (metacercariae)	14.00	0.22±0.20	1.57±1.06	*Geophagus brasiliensis*	Eyes, outer surface of the bladder
	Diplostomum sp. (metacercariae)	4.00	0.10±0.18	2.50±1.00	*Geophagus brasiliensis*	Eyes, outer surface of the bladder
	*Posthodiplostomum macrocotyle** *(metacerraride)*	88.00	10.92±2.10	12.40±1.23	*Geophagus brasiliensis*	Eyes, oral cavity, stomach, outer surface of the bladder Eyes

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
Digenea	*Posthodiplostomum* sp. (metacercariae)	4.50	0.08±0.15	1.70±1.10	*Geophagus brasiliensis*	Eyes
	Clinostomum complanatum (metacercariae)	20.00	0.77±0.07	3.83±0.33	*Gymnotus carapo*	Stomach
	Austrodiplostomum compactum (metacercariae)	7.00	0.10±0.01	1.50±0.20	*Gymnotus carapo*	Stomach
	Clinostomum complanatum (metacercariae)	6.00	0.18±0.10	3.00±2.10	*Hoplosternum littorale*	Eyes
	Herpetodiplostomum caimancola (metacercariae)	11.00	0.28±0.30	2.54±0.87	*Hoplosternum littorale*	Intestine
	Magnivitellinum corvitellinum	61.00	1.45±2.10	2.37±1.21	*Hoplosternum littorale*	Stomach
	Austrodiplostomum compactum (metacercariae)	3.22	0.03±0.005	1.00±0.18	*Hypostomus affinis*	Stomach
	Creptotrema creptotrema	61.00	27.33±3.80	44.72±6.23	*Leporinus conirostris*	Stomach, intestine
	Austrodiplostomum compactum (metacercariae)	37.50	0.97±0.06	2.58±0.15	*Loricariichthys castaneus*	Stomach
	Ascocotyle sp. (metacercariae)	11.76	0.20±0.02	1.75±0.16	*Mugil liza*	Gills
	Haplosplanchnidae gen. sp.	17.64	0.29±0.02	1.66±0.12	*Mugil liza*	Intestine
	Hysterolecitha brasiliensis	20.58	1.29±0.12	6.28±0.58	*Mugil liza*	Stomach, intestine
	Saccocoelioides elongatus	23.52	6.20±0.77	26.37±3.27	*Mugil liza*	Intestine
	Clinostomum complanatum (metacercariae)	15.0	1.40±0.07	0.20±0.01	*Oligosarcus hepsetus*	Eyes, palate, Intestine
	Austrodiplostomum compactum (metacercariae)	5.00	0.05±0.005	1.00±0.11	*Pimelodus maculatus*	Eyes, intestine
	Diplostomum sp. (metacercariae)	15.00	0.50±0.05	3.33±0.35	*Pimelodus maculatus*	Eyes, intestine

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
Digenea	*Clinostomum detruncatum* (metacercariae)	26.66	4.83±0.48	18.12±1.81	*Rhamdia quelen*	Gills, fins, operculum, wattles, muscle, surface
	Clinostomum detruncatum (metacercariae)	11.70	0.20±1.30	1.70±1.90	*Trachelyopterus striatulus*	Muscle
	Austrodiplostomum compactum (metacercariae)	1.70	0.02±0.30	1.00±0.50	*Trachelyopterus striatulus*	Eyes
	Posthodiplostomum macrocotyle (metacercariae)	3.30	0.03±0.45	1.00±0.57	*Trachelyopterus striatulus*	Stomach
Hirudinea	*Placobdella* sp.	5.70	0.30±0.10	2.10±1.30	*Astronotus ocellatus*	Gills
	Piscicolidae gen. sp.	10.00	0.13±0.01	1.33±0.14	*Centropomus undecimalis*	Gills
	Placobdella sp.	5.00	0.05±0.004	1.00±0.07	*Cyphocharax gilbert*	Gills
	Glossiphoniidae gen. sp.	10.00	0.16±0.40	1.60±0.40	*Geophagus brasiliensis*	Gills, oral cavity
	Placobdella sp.	2.00	0.02±0.50	1.00±1.50	*Geophagus brasiliensis*	Gills
	Glossiphonidae gen. sp.	3.00	0.03±1.18	1.00±0.18	*Gymnotus carapo*	Gills
	Glossiphoniidae gen. sp.	20.00	0.72±0.60	3.60±2.40	*Hoplosternum littorale*	Gills
	Placobdella sp.	3.00	0.04±0.10	1.33±0.90	*Hoplosternum littorale*	Gills
	Placobdella sp.	32.25	0.6±0.03	1.80±0.10	*Hypostomus affinis*	Gills
	Helobdella sp.	15.62	0.22±0.02	1.40±0.12	*Loricariichthys castaneus*	Gills
	Helobdella sp.	2.50	0.02±0.004	1.00±0.16	*Pimelodus maculatus*	Gills
	Piscicolidae gen. sp.	3.33	0.03±0.01	1.00±0.18	*Rhamdia quelen*	Gills
	Helobdella sp.	1.70	0.02±0.40	1.00±1.20	*Trachelyopterus striatulus*	Gills

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
Mollusca	Glochidia (larvae)	8.60	0.60±1.00	7.00±1.80	*Astronotus ocellatus*	Gills
	Glochidia (larvae)	2.00	0.24±0.50	12.00±1.20	*Geophagus brasiliensis*	Gills
Monogenea	*Gussevia asota*	65.70	7.37±0.23	11.21±0.36	*Astronotus ocellatus*	Gills
	Gussevia astronoti	71.40	5.23±0.15	7.32±0.21	*Astronotus ocellatus*	Gills
	Gyrodactylus sp.	10.00	0.37±0.03	3.75±0.29	*Astyanax bimaculatus*	Gills
	Gyrodactylus sp.	10.00	0.30±0.02	3.00±0.23	*Astyanax parahybae*	Gills
	Anakhonnia brasiliana	30.00	0.83±0.05	2.77 ±0.16	*Centropomus undecimalis*	Gills
	Rhabdosynochus hargisi	66.60	6.63±0.31	9.95±0.46	*Centropomus undecimalis*	Gills
	Rhabdosynochus sp.	53.30	3.56±0.18	6.68±0.35	*Centropomus undecimalis*	Gills
	Gussevia tucunarense	27.00	2.15±0.26	8.00±0.96	*Cichla ocellaris*	Gills
	Gussevia undulata	19.00	1.42±0.19	7.40±0.99	*Cichla ocellaris*	Gills
	Sciadicleithrum ergensi	15.00	0.50±0.07	3.25±0.49	*Cichla ocellaris*	Gills
	*Hyperopletes malmbergi**	22.58	0.45±0.03	2.00±0.14	*Hypostomus affinis*	Gills
	Phanerothecioides agostinhoi	67.74	4.03±0.21	5.95±0.31	*Hypostomus affinis*	Gills
	Trinigyrus hypostomatis	80.64	21.1±0.97	26.28±1.20	*Hypostomus affinis*	Gills
	Jainus sp.	13.33	1.66±0.25	12.50±1.87	*Leporinus copelandii*	Gills
	Scleroductus yuncensi	3.33	0.03±0.01	1.00±0.18	*Leporinus copelandii*	Gills
	Demidospermus sp.	62.50	19.75±0.76	31.6±1.22	*Loricariichthys castaneus*	Gills
	Ligophorus brasiliensis	20.58	0.94±0.08	4.57±0.38	*Mugil liza*	Gills
	Ligophorus guanduensis	20.58	0.79±0.06	3.85±0.31	*Mugil liza*	Gills
	Ligophorus lizae	11.76	0.23±0.02	2.00±0.17	*Mugil liza*	Gills
	Ligophorus tainhae	23.52	2.26±0.19	9.62±0.79	*Mugil liza*	Gills
	*Anacanthorus paraspathulatus**	76.47	19.82±2.96	25.92±3.88	*Mylossoma aureum*	Gills
	Demidospermus armostus	40.00	5.65±0.23	14.12±0.58	*Pimelodus maculatus*	Gills
	Demidospermus leptosynophallus	75.00	40.22±1.14	53.63±1.52	*Pimelodus maculatus*	Gills

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
	Demidospermus paravalenciennesi	60.00	11.82±0.46	19.70±0.78	*Pimelodus maculatus*	Gills
	Aphanoblastella mastigatus	66.66	34.53±1.97	51.80±2.95	*Rhamdia quelen*	Gills
	Cosmetocleithrum sp.	95.00	40.03±4.50	42.14±4.80	*Trachelyopterus striatulus*	Gills
Myxozoa	*Henneguya* sp.	80.00	—	—	*Astyanax bimaculatus*	Gills
	Henneguya sp.	65.00	—	—	*Astyanax parahybae*	Gills
	Myxobolus sp.	6.70	—	—	*Centropomus undecimalis*	Gills
	Henneguya cyphocharax	85.00	—	—	*Cyphocharax gilbert*	Gills
	Henneguya guanduensis	83.00	—	—	*Hoplosternum littorale*	Gills
	Henneguya sp.	11.00	—	—	*Leporinus conirostris*	Gills
	Henneguya sp.	40.00	—	—	*Leporinus copelandii*	Gills
	Myxobolus sp.	5.88	—	—	*Mugil liza*	Gills
	Henneguya sp.	52.50	—	—	*Oligosarcus hepsetus*	Gills
Nematoda	*Contracaecum* sp. (larval)	2.80	0.03±0.20	1.00±0.80	*Astronotus ocellatus*	Mesenteries
	Procamallanus (Spirocamallanus) hilarii	2.50	0.025±0.004	1.00±0.16	*Astyanax bimaculatus*	Intestine, pyloric diverticula
	Procamallanus (Spirocamallanus) hilarii	5.00	0.05±0.005	1.00±0.11	*Astyanax parahybae*	Intestine
	Contracaecum sp. (larval)	3.30	0.50±0.09	15.0±2.74	*Centropomus undecimalis*	Mesenteries
	Rhabdochona sp.	6.70	0.13±0.02	2.00±0.25	*Centropomus undecimalis*	Intestine
	Procamallanus (Procamallanus) peraccuratus	15.00	1.42±0.18	9.25±1.18	*Cichla ocellaris*	Intestine
	Cosmoxynemoides aguirrei	23.00	0.60±0.02	2.40±0.11	*Cyphocharax gilbert*	Intestine
	Raphidascaris sp.(larval)	3.40	0.05±0.005	1.50±0.14	*Cyphocharax gilbert*	Intestine

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
Nematoda	*Travnema araujoi*	10.00	0.20±0.008	1.50±0.08	*Cyphocharax gilbert*	Intestine
	Contracaecum sp. (larval)	6.00	0.06±0.02	1.00±0.50	*Geophagus brasiliensis*	Mesenteries
	Capillariidae gen. sp.	3.00	0.03±0.18	1.00±0.18	*Gymnotus carapo*	Intestine
	Contracaecum sp. (larval)	33.00	0.57±0.03	1.70±0.09	*Gymnotus carapo*	Stomach, mesenteries, intestine
	Procamallanus (*Procamallanus*) *peraccuratus*	7.00	0.30±0.04	4.50±0.66	*Gymnotus carapo*	Intestine
	Capillaridae gen. sp.	6.00	0.07±0.05	1.17±1.20	*Hoplosternum littorale*	Intestine
	Goezia sp.	2.00	0.02±0.01	1.00±0.80	*Hoplosternum littorale*	Intestine
	Paracapillaria piscicola	3.22	0.03±0.005	1.00±0.18	*Hypostomus affinis*	Stomach
	Cucullanus (*Cucullanus*) *brevispiculus*	6.66	0.06±0.01	1.00±0.13	*Leporinus copelandii*	Intestine
	Procamallanus (*Spirocamallanus*) *inopinatus*	6.66	0.10±0.01	1.50±0.20	*Leporinus copelandii*	Intestine
	Contracaecum sp. (larval)	6.25	0.09±0.01	1.50±0.19	*Loricariichthys castaneus*	Mesenteries
	Cucullanus (*Cucullanus*) *grandistomis*	2.94	0.03±0.005	1.00±0.17	*Mugil liza*	Intestine
	Hysterothylacium sp. (larval)	2.94	0.03±0.005	1.00±0.17	*Mugil liza*	Intestine
	Spinoxyuris annulata	88.23	203.88±13.29	231.06±15.06	*Mylossoma aureum*	Intestine
	Cucullanus (*Cucullanus*) *pinnai pinnai* *	45.00	0.85±0.03	1.88±0.06	*Pimelodus maculatus*	Intestine
	Rhabdochona uruyeni	5.00	0.07±0.01	1.5±0.17	*Pimelodus maculatus*	Intestine
	Capillariidae gen. sp.	6.66	0.06±0.01	1.00±0.13	*Rhamdia quelen*	Intestine
	Contracaecum sp. (larval)	26.66	0.30±0.02	1.13±0.07	*Rhamdia quelen*	Mesenteries

(Table 1)

Parasite group	Parasite species	Prevalence	Mean	Mean	Host species	Site of infection
	Cucullanus sp.	3.33	0.20±0.04	6.00±1.09	*Rhamdia quelen*	Intestine
	Contracaecum sp. (larval)	1.70	0.02±0.10	1.00±0.60	*Trachelyopterus striatulus*	Liver
	Cucullanus sp.	1.70	0.04±0.30	2.00±1.10	*Trachelyopterus striatulus*	Intestine
	Hysterothylacium sp. (larval)	1.70	0.07±0.28	4.00±2.80	*Trachelyopterus striatulus*	Mesenteries
	Paracapillaria piscicola	3.40	0.03±0.20	1.00±0.90	*Trachelyopterus striatulus*	Intestine
	Procamallanus (*Procamallanus*) *peraccuratus*	6.70	0.07±0.38	1.00±0.60	*Trachelyopterus striatulus*	Intestine

a total of 69% were parasitized by at least one species of metazoan parasite. The percentage of parasitism was 55% for endoparasite and 45% for ectoparasites.

The monogeneans had higher species richness at component community level. Of all the parasites found, the digenean had lower specificity, since the metacercaria *Austrodiplostomum compactum* (Lutz, 1928) was found parasitizing nine different species of fish. Of all the species of parasites collected only four showed positive correlation between the hosts' total length and abundance: in *Geophagus brasiliensis* (Quoy and Gaimard, 1824) the digenean *Posthodiplostomum macrocotyle* Dubois, 1937 (r=-0,289; p=0,041), in *Hypostomus affinis* (Steindachner, 1877) the monogenean *Hyperopletes malmbergi* Boeger, Kritsky and Belmont- Jégu, 1994 (r=0,394; p=0,028), in *Mylossoma aureum* (Spix and Agassiz, 1829) the monogenean *Anacanthorus paraspathulatus* Kritsky, Boeger and van Every, 1992 (r=0,484; p=0,049) and in *Pimelodus maculatus* Lacépède, 1803 the nematoda *Cucullanus* (*Cucullanus*) *pinnai pinnai* Travassos, Artigas and Pereira, 1928 (r=0,513; p=0,001).

Centropomus undecimalis (Bloch, 1792) showed the highest mean parasite diversity (H)=0.57±0.42 and Margalef's richness index (d)=0.64±0.48. The values found for the index of interactivity CC_{50} in parasite communities in fishes from Gaundu river were high, indicative of isolationist communities.

The host's total length was positively correlated with richness (r=0.999, p=0.00), but not with either $\Delta+$ (r=-0.169; p=0.563) or $\Lambda+$ (r=0.03, p=0.917). The richness was not significantly correlated with $\Delta+$ (r=-0.017, p =0.558) nor with $\Lambda+$ (r=0.032, p=0.912), showing that species with high parasite richness does not necessarily have high taxonomic distinctness and variance. The number of fish examined was not correlated with richness (r=0.223, p =0.602), with taxonomic distinctness (r=-0.119, p =0.454), or with the variance (r=0.031, p =0.908), showing that these indexes are independent of the sampling effort.

Of the categorical variables considered, only two significant results were obtained: $\Delta+$ varied significantly between schooling and non-schooling fish species (t=2.527, p=0.026) and among fish species with different trophic category (detritivores and omnivores) (t=2.905, p=0.033). Omnivores and schooling fish species had higher values of $\Delta+$ than other groups.

DISCUSSION

The results of this study indicate that the parasite communities of fish in the Guandu River were characterized by low parasite species richness and evenness, by isolationist communities and by greater values of taxonomic diversity in omnivores and schooling fish species.

According to Kennedy (2009) all parasite species have a niche selection to a greater or lesser degree, but isolationist communities have species poor and the species are independent of each other. By contrast, interactive communities have highest species richness. Communities could be located anywhere along this continuum, and those of freshwater fish tend to be found towards the isolationist end.

Our results suggesting that host feeding habits and the formation of schools may influence the taxonomic diversity, since omnivores and schooling fish species had higher parasite diversity than other groups. According Luque *et al.* (2004) many researches have found that schooling fish species are used by more species of parasites than solitary species, for both external parasites and all parasites combined. The fact of omnivores fish species present greater diversity can also be explained, because the greater the variety of food, the greater the intake of various intermediate hosts and easier to contamination by parasites is acquired via the food web.

A study by Takemoto *et al.* (2005) in the floodplain of the upper Paraná River found that parasite species richness in freshwater fish species was not associated with several host characteristics, with the exception of host population density. However, in the study by Luque *et al*. (2004), the fish size proved to be the main predictor of total parasite species richness in marine fish. This result was also found in this study. According to Luque *et al.* (2004) following from island biogeographical theory larger-bodied hosts should be able to accommodate more parasite species than small ones; they may also incur higher exposure to internal parasites because of the quantities of food they ingest, and to external parasites because their larger surface area facilitates contact with infective stages.

Considering both the approach and the results, the present study includes both key improvements on earlier studies of this kind and novel findings, making its contribution particularly relevant. The majority of earlier studies on the richness of freshwater fish parasites have used data from fish species that do not occur in the same geographical areas, with exception to work of Takemoto *et al.* (2005). The present study focused on a set of fish species from the same general area (Guandu river), thus minimizing any differences in parasite availability. In addition, this study was the first to incorporate the average taxonomic distinctness of the assemblage and its variance as a measure of taxonomic diversity in freshwater fish. For data, all study in freshwater fish has used species richness study in freshwater fish has used species richness as their sole measure of the diversity of parasite assemblages. According to Luque *et al.* (2004) the richness is a convenient measure, but it does not capture all facets of diversity. It ignores the evolutionary relationships among species coexisting in an assemblage. Applied to parasite assemblages, measures of diversity that incorporate information on the relationships among parasite species can shed light on how the assemblage has been structured.

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Table 2. Number of hosts examined (*N*), total prevalence P(%), mean total abundance (MA), mean total intensity (MI), mean length of hosts (ML), mean total species richness (MR), parasites richness and Margalef's richness index (d) of metazoan parasites from Guandu River, State of Rio de Janeiro, Brazil.

Hosts	(*N*)	P(%)	MA	MI	ML (cm)	MR	Parasite richness §	D
Astronotus ocellatus	35	74.00	13.71±0.38	18.46±0.51	20.44	1.77±1.23	2(5)	0.43±0.41
Astyanax bimaculatus	40	30.00	0.95±0.05	3.16±0.15	9.92	0.37±0.58	2(2)	0.03±0.12
Astyanax parahybae	40	35.00	0.65±0.03	1.86±0.08	10.39	0.35±0.48	2(2)	0
Centropomus undecimalis	31	90.00	18.73±0.57	20.81±0.27	28.75	2.76±1.63	7(5)	0.64±0.48
Cichla ocellaris	26	100.00	32.50±2.10	32.50±2.10	26.36	2.30±1.31	3(4)	0.51±0.46
Cyphocharax gilbert	60	58.00	5.50±0.002	9.42±0.004	16.32	0.86±0.89	6(1)	0.17±0.37
Geophagus brasiliensis	50	90.00	11.68±0.25	12.97±0.28	15.49	1.26±0.69	7(3)	0.19±0.30
Gymnotus carapo	30	67.00	2.33±0.10	3.50±0.15	36.46	1.00±0.83	9(1)	0.33±0.55
Hoplosternum littorale	10	60.00	2.91±0.05	4.85±0.08	19.65	1.03±1.13	5(2)	0.25±0.52
Hypostomus affinis	31	87.00	26.35±1.09	30.25±1.26	27.75	2.09±1.30	2(5)	0.46±0.38
Leporinus conirostris	18	61.00	27.33±3.80	44.72±6.23	36.60	0.72±0.57	1(1)	__
Leporinus copelandii	30	27.00	1.86±0.25	7.00±0.96	34.75	0.70±0.75	2(3)	0.01±0.05
Loricariichthys castaneus	32	75.00	21.06±0.76	28.08±1.01	27.90	1.25±0.95	2(3)	0.21±0.34
Mugil liza	34	79.00	12.50±0.83	15.74±1.04	34.05	1.82±1.78	6(7)	0.48±0.66
Mylossoma aureum	17	100.00	223.70±12.96	223.70±12.96	15.66	1.64±0.49	1(1)	0.18±0.22
Oligosarcus hepsetus	40	25.00	0.57±0.04	2.30±0.17	16.61	0.25±0.44	2(1)	0
Pimelodus maculatus	40	100.00	59.42±1.50	59.42±1.50	22.92	2.57±1.22	5(5)	0.42±0.28
Rhamdia quelen	32	80.00	40.16±1.99	50.20±2.49	32.68	1.46±1.00	5(3)	0.21±0.25
Tilapia rendalii	30	84.00	2.8±0.09	3.36±0.10	22.14	0.83±0.38	0(1)	__
Trachelyopterus striatulus	60	95.00	40.83±0.64	42.98±0.67	19.20	1.46±0.74	8(3)	0.16±0.22

(§) Endoparasites and ectoparasites (in parentheses).

Table 3. Brillouin's diversity index (*H*), Pielou's evenness index (J'), dominant taxon, Bray-Curtis similarity index, Berger-Parker dominance index, average taxonomic distinctness (Δ^{+}) and variance in taxonomic distinctness (Λ^{+}) of metazoan parasites from Guandu river, State of Rio de Janeiro, Brazil.

Hosts	(*H*)	J'	Dominant taxon	Bray-Curtis	Berger-Parker	Δ^{+}	Λ^{+}
Astronotus ocellatus	0.45±0.34	0.62±0.43	Monogenea	41.70 (33.90-48.40)	0.45±0.30	95.60	311.30
Astyanax bimaculatus	0.02±0.09	0.04±0.19	Digenea	8.10 (6.10-9.50)	0.31±0.46	__	__
Astyanax parahybae	0	0	Digenea	6.30(4.40-7.70)	0.35±0.48	__	__
Centropomus undecimalis	0.57±0.42	0.60±0.39	Monogenea	33.04 (26.90-38.40)	0.57±0.29	87.50	176.30
Cichla ocellaris	0.31±0.32	0.45±0.41	Cestoda	43.10 (38.60-48.06)	0.80±0.20	83.80	589.60
Cyphocharax gilbert	0.08±0.16	0.16±0.32	Digenea	13.60 (11.70-15.80)	0.51±0.46	91.60	68.89
Geophagus brasiliensis	0.11±0.18	0.20±0.32	Digenea	52.10 (48.80-55.30)	0.85±0.28	92.60	341.70
Gymnotus carapo	0.13±0.19	0.31±0.46	Nematoda	9.00 (5.90-13.00)	0.52±0.42	94.90	115.70
Hoplosternum littorale	0.13±0.25	0.19±0.37	Digenea	20.40 (17.80-22.60)	0.50±0.45	90.10	355.50
Hypostomus affinis	0.31±0.26	0.43±0.34	Monogenea	42.90 (36.40-48.50)	0.72±0.30	90.90	278.30
Leporinus conirostris	__	__	Digene	27.70 (22.70-27.70)	__	__	__
Leporinus copelandii	0	0.005±0.03	Myxozoa	2.20(1.40-2.90)	0.26±0.45	89.60	176.30
Loricariichthys castaneus	0.13±0.20	0.23±0.33	Monogenea	32.90 (28.70-37.40)	0.67±0.41	97.94	24.80
Mugil liza	0.26±0.40	0.32±0.42	Monogenea	9.40 (7.06-12.20)	0.62±0.39	80.60	642.10
Mylossoma aureum	0.14±0.18	0.25±0.32	Nematoda	59.50 (49.60-66.90)	0.92±0.13	__	__
Oligosarcus hepsetus	0	0	Digenea	4.70 (3.10-5.40)	0.25±0.44	__	__
Pimelodus maculatus	0.46±0.31	0.51±0.34	Monogenea	43.70 (37.90-490)	0.78±0.17	87.50	556.60
Rhamdia quelen	0.12±0.20	0.19±0.27	Monogenea	9.60 (6.60-13.20)	0.73±0.39	96.10	104.70
Tilapia rendalii	__	__	Crustacea	55.10(55.10-55.10)	__	__	__
Trachelyopterus striatulus	0.07±0.13	0.11±0.19	Monogenea	60.90 (58.10-63.50)	0.92±0.22	92.60	35.80

Table 4. Summary of the data (obtained from Fishbase) on the 20 fish species included in the analyses.

Hosts	**Family**	**Mean length of hosts (cm)**	**Formation of schools** [*]	**Environment**[§]	**Trophic category**	**Potamodromous**[‡]	**Diadromous**[†]
Astronotus ocellatus	Cichlidae	45.70	1	2	4	2	2
Astyanax bimaculatus	Characidae	17.50	1	2	4	1	2
Astyanax parahybae	Characidae	5.60	1	2	4	2	2
Centropomus undecimalis	Centropomidae	140.00	1	3	4	2	1
Cichla ocellaris	Cichlidae	74.00	1	2	4	2	2
Cyphocharax gilbert	Curimatidae	12.60	1	2	3	1	2
Geophagus brasiliensis	Cichlidae	28.00	1	2	2	1	2
Gymnotus carapo	Gymnotidae	60.00	2	2	4	1	2
Hoplosternum littorale	Callichthyidae	24.00	1	1	4	2	2
Hypostomus affinis	Loricariidae	39.70	2	3	3	2	2
Leporinus conirostris	Anostomidae	24.50	1	2	3	1	2
Leporinus copelandii	Anostomidae	23.00	1	2	3	1	2
Loricariichthys castaneus	Loricariidae	25.00	2	1	3	2	2
Mugil liza	Mugilidae	80.00	1	1	1	2	1
Mylossoma aureum	Characidae	20.00	1	2	3	1	2
Oligosarcus hepsetus	Characidae	23.80	1	2	4	2	2
Pimelodus maculatus	Pimelodidae	36.00	1	2	3	1	2
Rhamdia quelen	Heptapteridae	35.00	2	2	4	1	2
Tilapia rendalii	Cichlidae	45.00	1	2	3	2	1
Trachelyopterus striatulus	Auchenipteridae	20.00	2	1	3	2	1

[*] (1) schooling, (2) non-schooling

[§] (1) benthic, (2) benthopelagic, (3) demersal

[þ] (1) detritivores, (2) herbivores, (3) omnivores, (4) carnivores

[‡] (1) potamodromous, (2) non-potamodromous

[†] (1) diadromous, (2) non-diadromous

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