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Short Communication

Effect of parasitism on the relative condition factor of *Astyanax bimaculatus* (Characiformes: Characidae) a freshwater fish from the Caatinga domain, Brazil

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Abstract: The present study aimed to evaluate the effect of parasitism on the condition factor of *Astyanax bimaculatus* (Linnaeus 1758) (Characiformes, Characidae), in Batateiras river, Salgado River basin, northeastern Brazil. A total of 242 host specimens were collected between August 2018 and February 2020. The host presented a community of metazoan parasites of 14 taxa, totaling 1,750 specimens collected, with a mean total abundance of 7.23 specimens per fish, being the class Monogenea, the most predominant taxonomic group. The relative condition factor (K_n) differed significantly between parasitized and non-parasitized individuals, in which the parasitized hosts presented higher values of K_n. The abundance of the monogeneans *Characithecium costaricensis* and *Diaphorocleidus* sp. showed positive and significant correlations with the K_n. Considering the sex of the host, males had a higher parasite burden than females, although females present higher values of K_n. The parasitic burden of hosts did not show significant differences between seasonal periods.

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Introduction

Parasites are key organisms of biodiversity and play an important ecological role, whether in population dynamics, species coexistence, or trophic interactions (Poulin, 1999; Hugot et al., 2001; Lefèvre et al., 2009). The parasite-host relationship can affect the entire community through its effects on species distribution and abundance (Horwitz and Wilcox, 2005). According to Bauer (1961), Gibbs (1985), and Le Cren (1951), parasites may have a negative effect on their hosts, which is reflected in a decrease in health conditions, reproductive fitness, and food conversion for use in cyclic activities.

Astyanax bimaculatus (Linnaeus, 1758) (Characiformes: Characidae), popularly known as "lambari do rabo amarelo" (Mirande, 2010; Frick et al., 2018). Its distribution extends from northeastern Brazil and eastern South America to the Prata river basin (Sterba, 1973; Lima et al., 2003). According to Cordeiro et al. (2019), this species possesses adaptive plasticity associated with the reproductive mechanisms and strategies developed during its lifetime, allowing survival in the most varied habitats.

To date, it has been recorded several parasitic associations to *A. bimaculatus* in several aquatic ecosystems in Brazil: *Clinostomum complanatum* (Rudolphi, 1814), *Procamallanus (Spirocamallanus) hillari* (Pinto & Deli, 1976) and *Polymorphus* sp. Luhe, 1911 in the Guandu River, Rio de Janeiro state (Abdallah et al., 2004); *Magnivitellinum simplex* (Kloss, 1966) in the Paraná river, Paraná state (Kohn et al., 2011); *Prostosthenhystera obesa* (Diesing, 1850) in the Paraná River, São Paulo state (Kohn et al., 1997); *P. (Spirocamallanus) inopinatus* (Artigas & Pereira, 1928), *P. (S.) hillari*, *Halipegus* sp. Looss, 1899 in the Mogi-Guaçu River, São Paulo state (Kohn and Fernandes, 1987); *Rhabdochona acuminata* (Molin, 1860) in the Lajes Reservoir, Rio de Janeiro state (Paraguassú and Luque, 2007); *Lernaea cyprinacea* (Linnaeus, 1758), weir in Antonio Prado municipality, Rio Grande do Sul state (Gallio et al., 2007); *Myxobolus* sp. in the Dantas river, Maranhão

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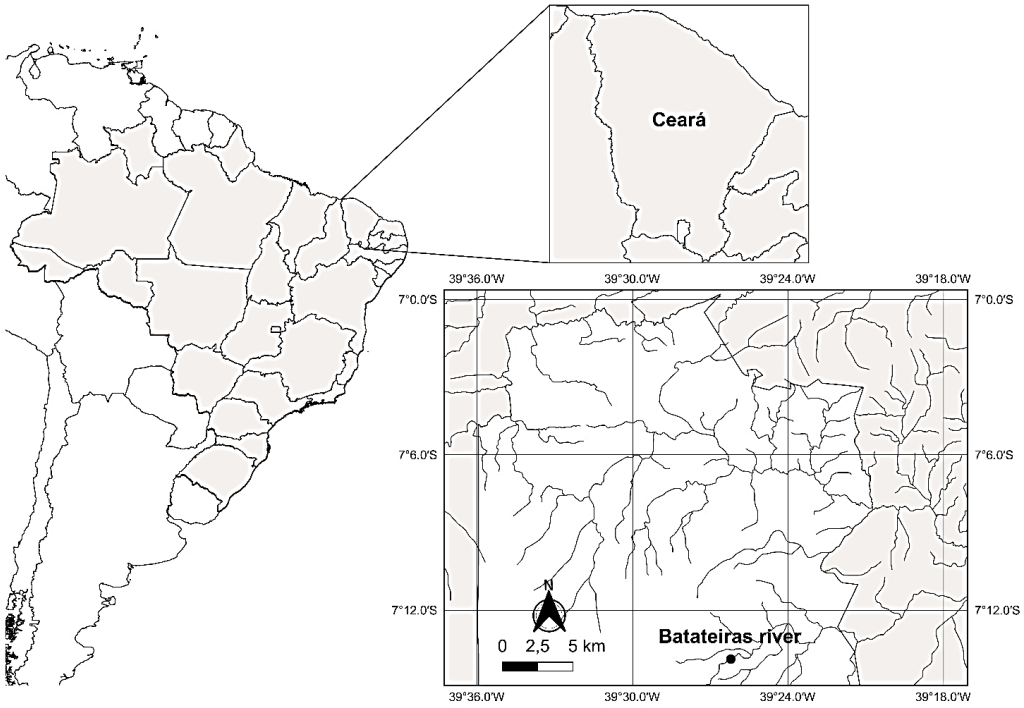

Figure 1. Sampling area of *Astyanax bimaculatus* collected from August 2018 to February 2020, Batateiras River, Salgado river basin, municipality of Crato, Ceará state, Brazil.

state (Silva et al., 2019); *L. cyprinacea*, *Urocleidoides* sp. Mizelle & Price, 1964, *Rabdochona* sp. Railliet, 1916, *P. (S.) hilarii*, *P. obesa*, *Dolops* sp. Audouin, 1837 in the São Francisco river, Sergipe state (Vasconcelos et al., 2013); and *Quadrigyrus torquatus* Van Cleave 1920 and *Quadrigyrus nickoli* Schmidt & Hugghins, 1973 in the Chumucuí river, Pará state (Fujimoto et al., 2013).

For fish, the relative condition factor (K_n) may explain the health and welfare aspects of these organisms (Mozsár et al., 2015), food resources (Bolger and Connoly, 1989), nutritional status and response to environmental factors (Brown and Murphy, 2004) as well as seasonal changes in environmental conditions (Gomiero and Braga, 2005). In this context, the present study aimed (1) to characterize the metazoan parasite community of *A. bimaculatus* from Batateiras River, Caatinga domain; and (2) to evaluate the effects of the parasitism on its relative condition factor (K_n).

Materials and methods

The specimens of *A. bimaculatus* were collected from August 2018 to February 2020 in Batateiras River, Salgado River basin, municipality of Crato, Ceará state (7º13'57.52"S; 39º26'25.46"W) (Fig. 1), in two seasonal periods (Dry – from August to October and Rainy – from November to February). The individuals were measured (standard length (SL) to the nearest 0.1 mm) and weighed (to the nearest 0.1 g) at the laboratory. All the specimens were examined for ectoparasites (eyes, nostrils and gills) and endoparasites (stomach, intestine, liver, gonads, swim bladder and muscles) according to the parasitological methods of collection, fixation, preservation and preparation described by Eiras et al. (2006). The parasite identification was performed according to Moravec (1998), Thatcher (2006) and Cohen et al. (2013).

The prevalence, mean abundance and mean intensity of the component communities were calculated according to Bush et al. (1997). The standard length (Ls) and total weight (Wt) of each host specimen were fitted in the Wt/Ls ratio. The values of the regression coefficients *a* and *b* were used in the estimates of expected weight values (We), using the equation $We = a.Ls^b$. The relative

condition factor (K_n) was then calculated, which is the quotient between the observed weight and the expected weight for a given length (K_n= Wt/We) (Le Cren, 1951).

Spearman's rank correlation coefficient (rs) was employed to verify correlations between K_n and parasite abundance (Zar, 2010). The Mann-Whitney test (U) was employed to verify the differences between the K_n of parasitized and non-parasitized hosts, hosts collected in dry and rainy seasonal periods, and males and females hosts. Also, the Mann-Whitney test (U) was used to verify differences in parasitic burden between males and females (Zar, 2010). The Chi-square test (X^2) was performed to verify differences in the prevalence of parasites between the two seasonal periods (dry and rainy) and the sex of the host. The statistical analyzes were performed using the Statistica software package version 7.1 (Statsoft Inc., 2005) and the statistical significance level adopted was $P \leq 0.05$.

Results and Discussion

The parasitic community of *A. bimaculatus* was composed of 14 taxa, totaling 1,750 specimens of the parasite, with a mean total abundance of 7.23 specimens per fish, being the class Monogenea, the taxonomic group more representative. Of the 242 host specimens examined, 132 (average size of 5.06±0.109) and 110 (average size of 5.98±0.117) were collected in the dry and rainy seasons, respectively. The parasites *Anachantocotyle anachantocotyle*, *Characithecium costaricensis*, *Characithecium* sp.1, *Characithecium* sp.2, *Diaphorocleidus* sp., *Urocleidoides trinidadensis, P.* (*Spirocamallanus*) *hilarii* and *Wallinia caririensis* were present in both seasonal periods. While the *Ascocotyle* sp., *Henneguya* sp., *Quadrigyrus* sp., Dactylogyridae gen. sp., Diplostomidae gen. sp. and *Spiroxys* sp. were present in only one season. *Characithecium costaricensis*, *Characithecium* sp. 1, *Diaphorocleidus* sp., *U. trinidadensis*, *Wallinia caririensis*and *P.* (*S.*) *hilarii* presented a prevalence higher than 10% (Table 1).

Parasitized individuals of *A. bimaculatus* showed K_n higher (0.89±0.03) than non-parasitized (0.65±0.02) (Z(U) = 4.7972; P<0.0001). The parasitic prevalence of *Characithecium* sp.1, *Diaphorocleidus* sp., *A. anachantocotyle* and *W. caririensis* were more prevalent in the rainy season. The host specimens presented an average K_n of 0.81±0.03 and 0.85±0.04 in the dry and rainy seasons, respectively; however, not significant (Z(U) = 1.5593; P<0.1189). The monogeneans *C. costaricensis* and *Diaphorocleidus* sp. showed positive and significant correlations between its abundance and the K_n of the analyzed hosts in both seasonal periods (Table 2).

Of the 242 fish examined, 80 were females (average size of 6.26±0.195), 157 were males (average size of 5.90±0.06), and five undefined sex. The female specimens presented an average K_n of 1.00±0.05, significantly higher than the male (0.75±0.03) (Z(U) =4.9088; P<0.0001). The male hosts showed a significantly higher parasitic burden (978 specimens) than females (772 specimens) (Z(U) 1.9485; P<0.0514). The parasitic prevalence of *C. costaricensis*, *Characithecium* sp.1, and *U. trinidadensis* were more prevalent in the female host.

The parasitic fauna of *A. bimaculatus* showed new occurrences and was predominantly by gill ectoparasite of class Monogenea. The second representative group was the digenetic trematodes recovered from the intestine, gills and eyes. The metacercariae of *Ascocotyle* sp. recovered from the gills of *A. bimaculatus* in Batateiras River, have already been described to *Satanoperca pappaterra* (Heckel, 1840) (Cichlidae) and *Crenicichla niederleinii* (Holmberg, 1891) (Cichlidae) in the Paraná River basin (Yamada et al., 2008). Furthermore, the parasites *Procamallanus* (*S.*) *hilarii* and Diplostomidae gen. sp. have already been registered for this host in other Brazilian ecosystems (Kohn and Fernandes, 1987; Abdallah et al., 2004, Vasconcelos et al., 2013).

In the present study, the relative condition factor (K_n) of the parasitized hosts has been shown greater

Table 1. Ecological descriptors of the parasitic community of *Astyanax bimaculatus*, Batateiras River, Salgado River basin, municipality of Crato, Ceará state, Brazil, in the dry and rainy seasonal periods. MA = mean abundance; MI = mean intensity; P(%) = prevalence and SE = standard error.

Parasite species	Dry			Rainy		
	P(%)	MA±SE	MI±SE	P(%)	MA±SE	MI±SE
Phylum Myxozoa						
Class Myxosporea						
Henneguya sp.	–	–	–	1.81	0.1727±0.1408	9.5±5.500
Phylum Platyhelminthes						
Class Monogenea						
Anachantocotyle anachantocotyle	4.54	0.09±0.046	2.0±0.683	13.63	0.29±1.007	2.1±0.496
Characithecium costaricensis	34.84	1.189 ±0.238	3.4±0.553	26.36	0.627±0.163	2.3±0.494
Characithecium sp.1	34.84	1.795±0.326	5.1±0.712	15.45	0.436±0.157	2.8±0.819
Characithecium sp.2	6.06	0.09±0.033	1.5±0.189	10.90	0.136±0.417	1.2±0.13
Dactylogyridae gen. sp.	–	–	–	0.90	0.009±0.009	1.0±0.000
Diaphorocleidus sp.	21.21	0.931±2.526	4.3±0.737	54.54	2.918±0.477	5.3±0.743
Urocleidoides trinidadensis	23.48	0.651±0.140	2.7±0.411	33.63	0.636±1.254	1.8±0.25
Class Trematoda						
Diplostomidae gen. sp.	1.51	0.045±0.033	3.0±1.00	–	–	–
Ascocotyle sp. (metacercariae)	4.54	0.09±0.042	2.0±0.516	–	–	–
Wallinia carириensis	13.63	0.924±0.370	6.7±2.324	28.18	3.209±0.803	11.3±2.285
Phylum Nematoda						
Class Chromadorea						
Procamallanus (Spirocamallanus) hilarii	10.60	0.143±0.04	1.3±0.169	13.63	0.272±0.078	2.0±0.323
Class Secernentea						
Spiroxys sp. (larvae)	2.27	0.03±0.018	1.3±0.333	–	–	–
Phylum Acanthocephala						
Class Eoacanthocephala						
Quadrigyrus sp.	–	–	–	1.81	0.018±0.012	1.0±0.000

than non-parasitized. This finding corroborates with Lizama et al. (2006) that found K_n significantly higher in parasitized fish than in non-parasitized. Although parasitism negatively affects the condition of the hosts (Bauer, 1970), the fish parasitized by the monogeneans *C. costaricensis* and *Diaphorocleidus* sp. showed positive and significant correlations between host K_n and their abundance in both seasonal periods. In this context, Moore (1987) pointed out that larger fish with high K_n can be able to harbor larger numbers of parasites and can tolerate greater intensities of infestations.

Considering the seasonal periods, *Characithecium* sp.1, *Diaphorocleidus* sp., *W. carириensis* and *A. anachantocotyle* were more dominant in the rainy period. Several studies indicate that limnological factors could influence the dynamic of host-parasite interactions (Barker and Coneb, 2000; Lizama et al., 2006). The study area exhibits an intermittent regime (Rosa et al., 2004). Therefore, the K_n of *A. bimaculatus* showed no significant differences during the rainy and drought seasons. This plasticity indicates that *A. bimaculatus* is probably a resilient species and well-adapted to this aquatic ecosystem.

Considering the sex of the host, males presented a higher parasitic burden than females. However, female specimens presented an average K_n significantly higher than males. The prevalence of three monogeneans species (*C. costaricensis*, *Characithecium* sp.1 and *U. trinidadensis*) was more prevalent in females, probably due to higher body mass and size, consequently, higher K_n than males. The distinction of parasitism about the sex of the

Table 2. Spearman's rank correlation coefficient (rs) between the relative condition factor (K_n) and the parasitic abundance of *Astyanax bimaculatus*, Batateiras river, Salgado river basin, municipality of Crato, Ceará state, Brazil, in the dry and rainy seasonal periods.

Parasite species	Dry		Rainy	
	rs	p	rs	p
Phylum Myxozoa				
Classe Myxosporea				
Henneguya sp.	–	–	0.033	0.7280
Phylum Platyhelminthes				
Class Monogenea				
Anachantocotyle anachantocotyle	-0.026	0.7674	-0.140	0.1429
Characithecium costaricensis	0.466	0.0001	0.266	0.0049
Characithecium sp.1	0.131	0.1344	0.148	0.1227
Characithecium sp.2	0.241	0.0053	0.008	0.9282
Dactylogyridae gen. sp.	-	-	0.164	0.086
Diaphorocleidus sp.	0.396	0.0001	0.305	0.0011
Urocleidoides trinidadensis	0.266	0.002	0.163	0.0886
Class Trematoda				
Diplostomidae gen. sp.	0.124	0.1559	–	–
Ascocotyle sp. (metacercariae)	-0.109	0.1095	–	–
Wallinia caririensis	0.473	0.0001	0.133	0.1630
Phylum Nematoda				
Class Chromadorea				
Procamallanus (Spirocamallanus) hilarii	-0.025	0.7727	0.338	0.0003
Class Secernentea				
Spiroxys sp. (larvae)	0.106	0.2257	–	–
Phylum Acanthocephala				
Class Eoacanthocephala				
Quadrigyrus sp.	–	–	0.220	0.0204

hosts may be linked to energy needs, different feeding habits or physiological differences of the individual (González and Acuña, 2000). For instance, males of *Cichla monoculus* Agassiz, 1831 (Cichlidae) from the Upper Paraná River floodplain presented intensities of infestation of cestodes significantly higher than the females (Machado et al., 2000). Males of *Astyanax altiparanae* Garutti & Britski, 2000 (Characidae) from the Chavantes reservoir showed a higher parasitic burden than females (Zica, 2008). On the other hand, females of *Salminus brasiliensis* (Cuvier, 1816) (Bryconidae) from the Upper Paraná River floodplain presented high levels of infestation by the acanthocephalans and nematodes (Karling et al., 2013).

In summary, the parasite communities of *A. bimaculatus* were characterized by high ectoparasite species richness, with monogeneans being numerically dominant; parasitized hosts showed the K_n higher than non-parasitized. Females could withstand a higher parasitic burden than males, and differences in K_n between seasonal periods. In general, it is expected that parasites cause deleterious effects on their host; therefore, it is difficult to define and measure those effects. This corroborates the finding of Kennedy (2009) and Price (1980) in which that there is no pattern or order in space or time in fish parasitological studies and that most of the populations of fish parasites live in conditions of imbalance, dominated by stochastic events, respectively.

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