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ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

HELMINTHES PARASITIZING *SEMAPROCHILODUS INSIGNIS* JARDINE, 1841 (OSTEICHTHYES: PROCHILODONTIDAE) FROM THE CENTRAL AMAZONIA (BRAZIL), AND THEIR RELATIONSHIP WITH THE HOST

HELMINTOS PARÁSITOS DE *SEMAPROCHILODUS INSIGNIS* JARDINE, 1841 (OSTEICHTHYES: PROCHILODONTIDAE) DEL CENTRO DE LA AMAZONÍA (BRASIL), Y SU RELACIÓN CON EL HOSPEDERO

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Abstract

This study describes the parasitic fauna and the host-parasite relationship of *Semaprochilodus insignis* Jardine, 1841 from Coari Lake, a tributary of the middle Solimões River (state of Amazonas, Brazil) in Central Amazonia. Of 56 fish examined, 23.2% had gills parasitized by *Gyrodactylus Gemini* Ferraz, Shinn & Sommerville 1994 (Monogenoidea: Gyrodactylidae), and the intestine by *Procamallanus inopinatus* Travassos, Artigas & Pereira, 1928 (Nematoda: Camallanidae). The highest rates of infection were caused by *G. gemini*. Even though the relative condition factor (Kn) was not affected by parasitism, there was a positive correlation between the intensity of both helminthes, the Kn and the total length of the hosts. This is the first report on the parasitic fauna of *S. insignis* with occurrences of *G. gemini* and *P. inopinatus* for this Neotropical host fromthe Amazonia.

Key words: Amazonia - Condition factor - Freshwater fish - Helminthes - Parasites.

Resumen

Este estudio describe la fauna de parásitos y la relación hospedero-parásito en *Semaprochilodus insignis* Jardine, 1841, encontrados en el Lago Coari, tributario en el centro del Rio Solimões (estado del Amazonas, Brasil) en la Amazonia central. De 56 peces examinados, el 23,2% tenía las branquias parasitadas por *Gyrodactylus gemini* Ferraz, Shinn y Sommerville 1994 (Monogenoidea: Gyrodactylidae) y el intestino por *Procamallanus inopinatus* Travassos, Artigas y Pereira, 1928 (Nematoda: Camallanidae). La tasa más alta de infección fue causada por *G. gemini*. El factor de condición relativa (Kn) no se vio afectado por el parasitismo, pero había una correlación positiva entre la intensidad de los helmintos y Kn, y la longitud total de los hospederos. Este es el primer registro de la fauna de parásitos de *S. insignis* con la ocurrencia de *G. gemini* y *P. inopinatus* para este hospedero Neotropical de la Amazonía.

Palabras clave: Amazonía - Factor de condición – Helmintos – Parásitos - Peces de agua dulce.

INTRODUCTION

In South America, there are six known species of Prochilodontidae of the genus *Semaprochilodus*. In the Amazon and Orinoco basins and in some rivers in Guyana, three species of this genus can be found: *Semaprochilodus insignis* Jardine, 1841; *Semaprochilodus taeniurus* Valenciannes, 1821 and *Semaprochilodus brama* Valenciannes, 1850. The jaraqui *S. brama* occurs only in the Tocantins-Araguaia and Xingu River. The jaraqui *S. insignis* and *S. taeniurus* are widely distributed in the Amazon River basin and in its tributaries (Castro & Vari, 2003; Oliveira *et al.*, 2003). Both species migrate twice a year towards nutrient-rich rivers and return to the same tributary with nutrient-poor waters, where they feed for 3 to 4 months. Adults of both species are found in flooded areas, in the main channel of rivers, in floodplain and in streams (Ruffino, 2005; Batista & Lima, 2010). In the Brazilian Amazonia, these fish are an important source of protein for the riverine populations (Soares *et al*., 2007; Batista & Lima, 2010) and are popularly known as jaraqui.

The continental extractive fishery of jaraqui *S. insignis* and *S. taeniurus* occurs in every state in northern Brazil and also in the state of Maranhão. In 2007, the production of these fish was 17,474.0 tons in which the contribution of the state of Amazonas was 16,086.0 tons (Ibama, 2007). These two species of jaraqui are the second most-caught fish in the State of Amazonas (Ruffino, 2005), with a 30.7% share of the total fishery production (Ruffino *et al.*, 2006). However, overfishing threatens the natural stocks of these two species (Ruffino, 2005), since they are not yet farmed for lack of fingerling production and knowledge about their biology.

The jaraqui *S. Insignis* is larger than the jaraqui *S. taeniurus* and it reaches its first sexual maturation with 22.0-23.5 cm when it is around two years old (Ruffino, 2005; Batista & Lima, 2010). It is diurnal and feeds on detritus, rotifers, microscopic and filamentous algae, but detritus and inorganic particles are predominant in its diet (Castelo, 1992; Soares *et al*., 2007; Batista & Lima, 2010). It forms schools and conducts spawning migration at the beginning of the rivers flooding season, from December through March (Ruffino, 2005; Soares *et al.*, 2007).

Among all vertebrate, fish are the ones with the highest rates of parasitic infection because the characteristics of the aquatic environment are conducive to the development and lifecycle of different groups of parasites (Guidelli *et al*., 2006; Takemoto *et al*., 2009; Silva *et al*., 2011), especially those of direct transmission. Therefore, studies on the impact of parasites on natural populations of fish are intended to increase knowledge about the host-parasite-environment relationships and the different strategies used by different parasites, as well as their ecological aspects (Feltran *et al*., 2004; Eiras *et al*., 2006; Guidelli *et al*., 2006; Silva *et al*., 2011).

Condition factor is an important tool for the study of fish welfare reflecting directly on its health. Analysis of variations in this indicator has been used to evaluate the effects of different parasites on hosts populations or individuals (Guidelli *et al*., 2006; Silva *et al*., 2011; Guidelli *et al*., 2011). Some parasites seem not to exert negatives effects on their hosts, while others can have deleterious effects in the health of the hosts.

Even though the jaraqui *S. insignis* is a species of the ichthyofauna that has great social and economic importance for the Amazonia, little is known about its parasitic fauna. The copepod *Ergasilus jaraquensis* Thatcher & Robertson, 1982 (Thatcher & Robertson, 1982) was described in gill filaments of jaraqui *S. insignis* collected in Manaus, in the state of Amazonas. The copepod *Gamidactylus jaraquensis* Thatcher & Boeger, 1984 (Thatcher & Boeger, 1984) was described in the nasal fossae of this same host from the Amazonas River. Eiras *et al*. (2005) described *Myxobolus insignis* Eiras, Malta, Varella and Pavanelli, 2005 parasitizing the gills of jaraqui *S. insignis* from the Amazonas River. The monogenoidea *Gyrodactylus gemini* Ferraz, Shinn & Sommerville 1994 was described parasitizing the body surface and fins of jaraqui *S. taeniurus* (Ferraz *et al*., 1994). However, all these studies aforementioned are taxonomic reports and none of them refers to the infection levels in *S. insignis*. Thus, the present study aimed to describe the parasitic fauna of *S. insignis* from Coari Lake, a tributary of the Middle Solimões River, in the state of Amazonas, Brazil, and also to study the host-parasite relationship.

MATERIAL AND METHODS

Fish and collection site

From April to June 2008, specimens of jaraqui *Semaprochilodus insignis* were collected from flooded areas (Fig. 1) of Coari Lake (04º00'582"S, 063º19'225'W), a tributary of the Middle Solimões River, in the municipality of Coari (state of

Amazonas, Brazil, in central Amazonia) for parasitological studies. All fish were collected with appropriate gillnets (ICMBio license: 11884-1) and transported to the laboratory of Universidade Federal do Amazonas (UFAM), Coari (AM).

Parasitological Examination
All fish were weighed (g) and measured in length (cm) and necropsy was performed for the analysis of parasites.
The gills and the gastrointestinal tract of each specimen were examined. These organs were removed and analyzed using a common light microscope and a stereo microscope. The methodology used for collecting, fixating (Eiras *et al*., 2006; Thatcher, 2006) and quantifying the parasites (Tavares-Dias *et al.,* 2001) followed previous recommendations. The identification of the collected parasites was done according to Moravec (1998), Ferraz *et al*. (1994) and Thatcher (2006). Ecological terms followed Bush et *al*. (1997) and Rohde *et al*. (1995).

Relative condition factor (Kn) and host - parasite relationship
The length and weight of the hosts were used to calculate the relative condition factor (Kn) of parasitized and non-parasitized fish according to Le-Cren (1951), and the differences were evaluated by t-test. Spearman's rank correlation coefficient (*rs*) was used to determine the possible correlations between the total length of the host and the number of parasites and to verify correlations between the number of monogenoideans and the relative condition factor (Zar, 1999).

Physicochemical parameters of the water
Levels of dissolved oxygen ($mg.L^{-1}$), water temperature (°C) and pH were measured at the time of fish collection. The water temperature ranged from 27.7 to 28.8 ºC; dissolved oxygen levels ranged from 4.2 to 5.3 mg/L and the pH ranged from 5.1 to 5.6.

RESULTS

Of the 56 jaraqui *S. insignis* examined, 23.2% were parasitized by *Gyrodactylus gemini* Ferraz, Shinn & Sommerville 1994 (Monogenoidea: Gyrodactylidae) and by *Procamallanus inopinatus* Travassos, Artigas & Pereira, 1928 (Nematoda: Camallanidae). However, the highest rates of infection were those by *G. gemini* in the gills (Table 1).

There was no significant difference ($p>0.05$) in the relative condition factor (Kn) of parasitized and non-parasitized fish (Table 2 and Fig. 2). However, a positive correlation was observed between the intensity of helminthes *G. gemini* and *P. inopinatus* and the total length of hosts ($r= 0.442$, $p = 0.021$), but not with the weight ($r= 0.156$, $p =0.137$). Nevertheless, the Kn showed a highly positive correlation with the intensity of helminthes (*G. gemini* and *P. inopinatus*) in the hosts (Fig. 3).

Table 1. Parasitological indexes in jaraqui *Semaprochilodus insignis* from the Coari Lake, middle Solimões River, State of Amazonas, Brazil.

Parameters	*G. gemini*	*P. inopinatus*
Examined fish	56	56
Parasitized fish	10	5
Prevalence (%)	17.8	8.9
Mean intensity	695.5	8.8
Abundance	124	0.8
Range	151-1629	3-19
Total number of parasites	6956	44
Mean relative dominance	0.994	0.006
Site of infection	Gills	Intestine

Table 2. Mean values ± standard deviation of body weight, total length and relative condition factor (Kn) in jaraqui *Semaprochilodus insignis* from the Coari Lake, middle Solimões River, State of Amazonas, Brazil. ns: Indicates that there was not significant difference (p>0.05) between groups by t-test.

Parameters	Non-Parasitized (n=43)	Parasitized (n=13)	*p*
Body weight (g)	245.8 ± 54.6	277.7 ± 64.0	0.082ns
Total length (cm)	26.1 ± 1.8	26.2 ± 2.1	0.823ns
Kn	1.000 ± 0.035	1.000 ± 0.021	0.861ns

Figure 1. Collection of tick-scaled jaraqui *Semaprochilodus insignis* to flooded area from the Coari Lake, middle Solimões River, State of Amazonas, Brazil.

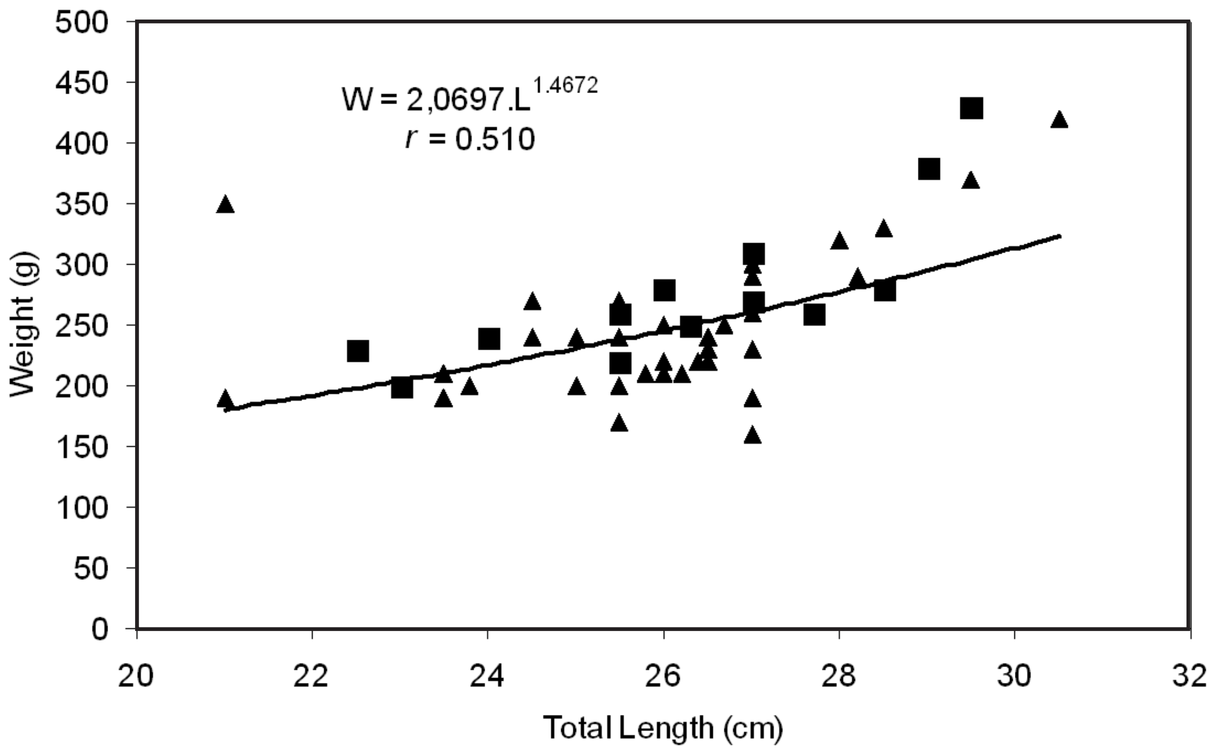

Figure 2. Length-weight relationship of parasitized (■) and non-parasitized (▲) jaraqui *Semaprochilodus insignis* (n=56) from the Coari Lake, middle Solimões River, State of Amazonas, Brazil.

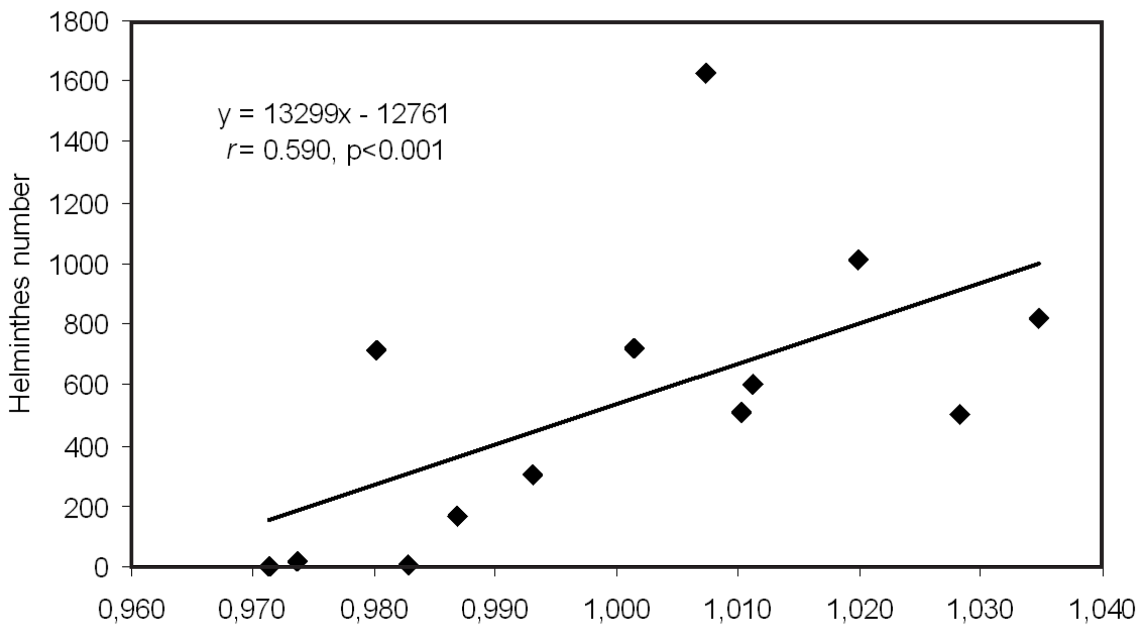

Figure 3. Correlation between Kn and intensity of helminthes parasites in jaraqui *Semaprochilodus insignis* from the middle Solimões River, State of Amazonas, Brazil.

DISCUSSION

Most species of Monogenoidea have a high degree of parasite host specificity, selecting only one host species or groups of hosts that are phylogenetically close (Cribb *et al*., 2002; & Buchmann & Brescani, 2006; Silva *et al*., 2011). Species of the genus *Gyrodactylus* are viviparous and the embryo develops inside the mother's womb and sexual and asexual reproduction alternate (Huyse *et al*., 2003; Tinsley, 2006). Almost all gyrodactylids are transferred directly from host to host, but others monogenoideans taxa, usually have a free-swimming oncomiracidium that finds and attaches to the host (Cribb *et al*., 2002; Tinsley, 2006).

Gyrodactylus gemini, a monogenoidea of jaraqui *S. taeniurus* (Ferraz *et al*., 1994; Thatcher, 2006) was found in the gills of thick-scaled jaraqui *S. insignis* from the Middle Solimões River. However, in some periods of the year, both the jaraqui *S. insignis* and the *S. taeniurus,* wich are species with ecologically similar habits, form schools that migrate together (Ruffino, 2005; Soares *et al*., 2007). These factors explain the infection by this same species of monogenoidean on gills of thick-scaled *S. insignis*, too.

In jaraqui *S. insignis* from the Coari Lake, a tributary of the Middle Solimões River, the infection rates by *G. gemini* were higher than those reported for *Prochilodus lineatus* Valenciennes, 1837 from the floodplain of the Paraná River that were infected by *Gyrodactylus* sp. (Lizama *et al*., 2006). In contrast, they were lower than the infection rates by *Gyrodactylus* sp. in *Carnegiella martae* Myers, 1927 from the middle Rio Negro (Tavares-Dias *et al*., 2010) and by *Cosmetocleithrum* spp. in *Oxydoras niger* Valenciennes, 1821 from Lago Coari (Silva *et al*., 2011). On the other hand, they were higher than the infection rates by *Gyrodactylus* sp. in the gills of *Paracheirodon axelrodi* Schultz, 1956 and *Carnegiella strigata* Günther, 1864, both ornamental fish from the middle Rio Negro, state of Amazonas (Tavares-Dias *et al*., 2010). Nevertheless, *Gyrodactylus* infrapopulation growth is highly influenced by environmental factors such as temperature, water chemistry and pollution, and also by biotic and host genetic factors (Tinsley, 2006).

In fish, the diversity of endohelminthes can vary according to the environment or the species of host, and it can be related to size, longevity and specially the diet of the host. The intermediate host is necessarily part of the diet of the definitive host. In addition, fish with a longer lifespan present more time of exposure to parasites, favoring cumulative processes in the host (Feltran *et al*., 2004; Guidelli *et al*., 2006; Takemoto *et al*., 2009).

Detritivorous fish such as the jaraqui *S. insignis* (Castelo, 1992; Soares *et al*., 2007; Batista & Lima, 2010) have showed low rates of parasitism by *P. inopinatus*, since they are primary consumers and occupy lower trophic levels in the food chain. They can act as paratenic, intermediate or final hosts for this endohelminth (Thatcher, 2006; Takemoto *et al.,* 2009; Silva *et al*., 2011). *Procamallanus inopinatus* is the most common and abundant species of Nematoda in Brazilian fish (Feltran *et al*., 2004; Takemoto *et al*., 2009) because it has no host specificity. Recently, Eiras *et al.* (2010) have listed this nematode as a parasite of 51 species of freshwater fish in Brazil. However, the number of hosts is greater, since the present study extends its occurrence to one more host in Brazil, in the central Amazonia.

In jaraqui *S. insignis* from the Coari Lake, in the Middle Solimões River, the rates of infection by *P. inopinatus* were lower than those reported for *Leporinus friderici* Bloch, 1794 and *Leporinus obtusidens* Valenciennes, 1836 from the dam of Nova Ponte, in Perdizes, state of Minas Gerais (Feltran *et al*., 2004) and for *Leporinus lacustris* Amaral-Campos, 1945 and *L. friderici* from the floodplain of the Paraná River (Guidelli *et al*., 2006). Moreover, the prevalence was lower than in *Astyanax altiparanae* Garutti & Britski, 2000 (Azevedo *et al*., 2007) from lakes of Campinas, in the state of São Paulo, while the intensity and abundance were higher. Even though nematodes rarely lead to mortality, these endohelminthes can cause damages to the physiology and behavior of fish and delays in their growth and sexual maturation, depending on the species, parasitized organ and intensity of infection (Feltran *et al*., 2004; Eiras *et al*., 2010). However, in *Leporinus macrocephalus* Garavello and Britski, 1988, infection by nematodes *Goezia leporini* Martins & Yoshitoshi, 2003 caused severe microcytic-hypochromic anemia (Martins *et al.*, 2004), due to pathogenicity of parasite.

The relative condition factor is an indicator of the welfane of fish (Le-Cren, 1951; Lizama *et al*., 2006; Guidelli *et al*., 2011; Silva *et al*., 2011) and therefore may be useful to detect the species of parasite that affects the health of the host fish (Santos & Brasil-Sato, 2006; Guidelli *et al*., 2011). However, in jaraqui *S. insignis* parasitized by helminthes *G. gemini* and *P. inopinatus*, the average Kn was equal to the standard (Kn=1.00), but the Kn and the length of the hosts increased with the intensity of these helminthes. In *Franciscodoras marmoratus* Reinhardat, 1874 from São Francisco River (Santos & Brasil-Sato, 2006) and *O. niger* from the Coari Lake (Silva *et al*., 2011), Kn was not influenced by parasitism either. Similarly, a positive correlation was described between the Kn of *O. niger* and the intensity of Monogenoidea *Cosmetrocleitrum* spp. (Silva *et al*., 2011), as well as between the Kn of *P. lineatus* and the abundance of monogenoidean *R. pseudocapsaloideum*, copepod *Gamispatulus* sp. and digenean *Saccocoelioides magnorchis* Thatcher, 1978 because larger fish with a higher Kn can endure relatively higher levels of parasitism (Lizama *et al*., 2006).

In conclusion, the results indicate the presence of few infectious forms in the flooded areas of collect of *S. insignis*. Thus, the health of host was not affected by the low parasitism. This was the first report on the rates of parasitic infection in *S. insignis* and also on the occurrence of *G. gemini* for this host examined in the central Amazonia.

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