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Investigating the diversity of fish parasites in the floodplain of the upper Paraná River: a long-term ecological monitoring

Investigando a diversidade de parasitas de peixes da planície de inundação do alto rio Paraná: um monitoramento ecológico de longa duração

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Abstract: Aim: The aim of this study was to present the description of new species of fish parasites in native and non-native hosts and the parasite interaction / host, available in studies for 37 years in the upper Paraná River floodplain. **Methods:** The sampling described in this study is part of a scientometric methodology, in which specific query expressions were used, together with the database available in the Nupelia Sector Library, through Theses and Dissertations. **Results:** A total of 44 species of parasites belonging to different groups were described for 27 species of fish of different orders. In these 37 years of studies, an increase 68% was observed in the number of parasite species, presenting a richness of 201 species in the floodplain, being: Monogenea, Digenea, Nematoda and Cestoda are the groups that present the largest records of species. More than 80 hosts have their parasite fauna registered and most studies are carried out with species of native hosts in the floodplain, being *Prochilodus lineatus* the host with the highest number of records. **Conclusions:** Parasitological studies are an important scientific tool for understanding the dynamics of ecological interactions in the natural environment, and knowledge of this diversity of organisms is continuous and necessary, and the results of the monitoring carried out in the floodplain during the last 37 years only reinforce this with a constant increase in the description of new species and new records of parasite-host interactions. In times of constant environmental loss and habitat fragmentation, it is of utmost importance to care for and preserve floodplains to maintain biodiversity.

Keywords: ichthyoparasites; parasitism; biodiversity; ecological study.

Resumo: Objetivo: O objetivo deste estudo, foi apresentar a descrição de novas espécies de parasitos de peixe em hospedeiros nativos e não nativos, a interação parasito/hospedeiro, com dados disponibilizados de 37 anos de estudos na planície de inundação do alto rio Paraná. **Métodos:** A amostragem descrita neste estudo faz parte de uma metodologia cienciométrica, na qual foram utilizadas expressões de consultas específicas, junto com o banco de dados disponíveis pela Biblioteca setorial do Nupelia, através de Teses e Dissertações. **Resultados:** Ao todo, 44 espécies de parasitas pertencentes a diferentes grupos foram descritas para 27 espécies de peixes de diferentes ordens. Atualmente, registrou-se um aumento de 68% no número de espécies de parasitas, apresentando uma riqueza de 201 espécies na planície de inundação, sendo: Monogenea, Digenea, Nematoda e Cestoda os grupos que apresentam os maiores registros de espécies. Mais de 80 hospedeiros tem sua fauna parasitária registrada e maioria dos estudos são realizados com espécies de hospedeiros nativos da planície, sendo *Prochilodus lineatus* o hospedeiro com o maior número de registros. **Conclusões:** Os estudos parasitológicos são uma ferramenta científica importante para entender a dinâmica das interações ecológicas em ambiente natural, e o conhecimento desta diversidade de organismos é contínuo e necessário, e os resultados do monitoramento realizado na planície durante os últimos 37 anos só reforçam isso com aumento constante de descrição de espécies novas e novos registros de interação parasito hospedeiro. Em tempos de perda constante de ambiente e fragmentação de habitats, é de extrema importância cuidar e preservar as planícies aluviais para manter a biodiversidade.

Palavras-chave: ictioparasitas; parasitismo; biodiversidade; estudo ecológico.

1. Introduction

Biodiversity describes the totality of diversity at all biotic levels, from genetic variation to ecosystem function (Purvis & Hector, 2000), and species are central to most diversity measures. The complexity of species definitions challenges our ability to determine how many species are present in a site (Agapow et al., 2004; Poulin et al., 2020), and it is important to understand biodiversity to fully appreciate important biological issues such as speciation, ecosystem function, species interaction (competition, symbiosis, predation and parasitism), ecological importance (productivity and food networks), and economic importance to humans (Hausdorf, 2011).

To verify all these ecological issues, they need a long period of study to observe frequent events and evaluate their effects. Floodplains, such as the upper Paraná River floodplain, are suitable for investigating changes in aquatic communities, since they have high environmental heterogeneity (e.g., lakes, rivers and permanent channels) and support high aquatic biodiversity (Thomaz et al., 2004). The upper Paraná River is 230 km long and is located between the Porto Primavera dam and the Itaipu reservoir and is considered the last dam-free extension of this river (Agostinho et al., 2004; Thomaz et al., 2007). The importance of such floodplains for the conservation of biodiversity and the maintenance of the functioning of the aquatic ecosystem is widely recognized. Therefore, three conservation units were created in the upper Paraná River floodplain, besides its inclusion as an Atlantic Forest Biosphere Reserve by MAB/Unesco (Agostinho et al., 2004).

Besides playing a key role in maintaining biodiversity, the floodplain has high diversity in its ichthyofauna, with approximately 200 species distributed in 126 genera, 41 families and 10 orders (Ota et al., 2018). Currently more than 50% of these fish species in the floodplain are introduced due to aquaculture activities (Orsi & Agostinho, 1999; Lima et al., 2016), aquarism (Padilla & Williams, 2004), sport fishing (Vitule et al., 2014; Ribeiro et al., 2017) and the construction of dams that can remove geographic barriers, being identified as an important vector for the introduction of fish species (Júlio Júnior et al., 2009; Daga & Gubiani, 2012; Vitule et al., 2012).

Studies on the floodplain show that the ichthyofauna present in the site, presents a great diversity of parasites (Kennedy & Bush, 1994; Pavanelli et al., 1997; Takemoto et al., 2009; Lehun et al., 2020). Transmission and dispersion of parasites are facilitated by the characteristics of these environments (Poulin, 2006), which can lead to differences in parasite levels, depending on the taxonomic group of the parasite and the availability of intermediate/definitive hosts. For example, inputs of allochthonous matter can lead to changes in the feeding behavior of hosts and, consequently, in the structure and composition of their parasites (Pavanelli et al., 1997; Kadlec et al., 2003; Yamada et al., 2017).

It is estimated that each fish species has on average 10 different parasite taxa (Takemoto et al., 2004), and the floodplain having a great diversity of hosts, probably has more than 2000 species of parasites and only about 10% are described and recorded (Takemoto et al., 2009; Lehun et al., 2020). The aim of this study was to present the description of new species of fish parasites in native and non-native hosts and the parasite interaction/host, available in studies for 37 years in the upper Paraná River floodplain.

2. Material and Methods

2.1. Study area

The study area is located between the states of Paraná and Mato Grosso do Sul with 36 sampling points distributed by three subsystems: Ivinhema River, Baia River and Paraná River (Figure 1).

Since 1983, the Núcleo de Pesquisas em Limnologia Ictiologia e Aquicultura (Nupélia) has contributed to ecological studies in the floodplain, supported by projects such as FINEP (Itaipu Binacional from 1986 to 1991) and PADCT (Programa de Apoio ao Desenvolvimento Científico e Tecnológico from 1992 to 1999). Currently, the Long-Term Ecological Research (LTER) – Site 6, at Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) is carried out with the participation of professors and researchers from the Course of Ciências Biológicas, Post-Graduate Program in Ecologia de Ambientes Aquáticos Continentais and the Post-Graduate Program in Biologia Comparada.

Among the research activities in the floodplain, ichthyoparasitology has been collaborating with records and descriptions of new species of parasites, besides ecological studies of biological invasion, introduction of new species and among other ecological theories, resulting in numerous works such as graduation and specialization monographs, general qualification exams, dissertations, theses and scientific articles published in national and international journals.

2.2. Data analysis

The data used in this paper were compiled from the papers by Pavanelli et al. (1997), Takemoto et al. (2009), and Lehun et al. (2020). These papers are points on an accumulation curve of records of parasite species in their hosts in the upper Paraná river floodplain, which can be surveyed using the SCOPUS database, where we used as query expression: [“Upper Paraná River Floodplain” OR “Paraná River” OR “Monogenea” OR “Digenea” OR “Cestoda” OR “Myxozoa “* AND NOT “Anuran”* AND NOT “snail”]. We limited only to the branch country ‘Brazil’ and subsequently only to the authors ‘Takemoto RM’ and ‘Pavanelli

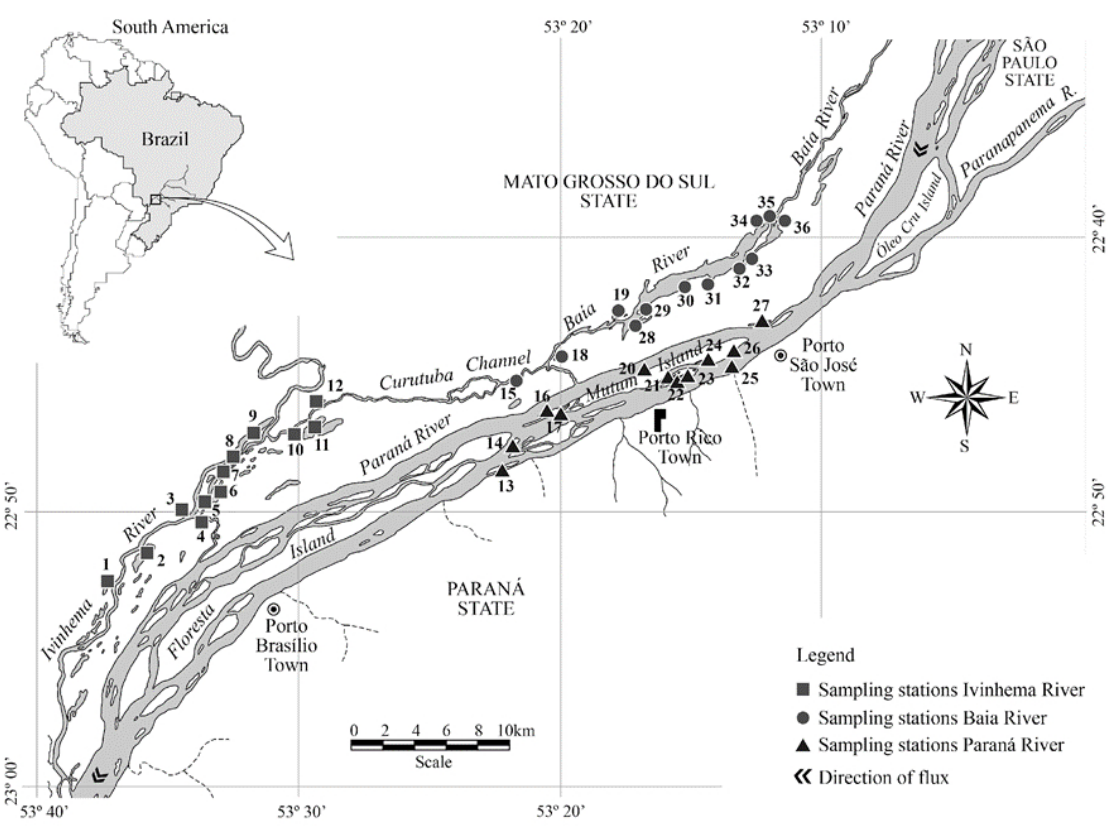

Figure 1. The upper Paraná River floodplain. From Jaime Luiz Lopes Pereira.

GC'. The results were saved with complete fields and saved in Bibtex format, and then analyzed using the Bibliometrix package (Aria & Cuccurullo, 2017) in the R Core Team Statistical Software (R Core Team, 2016). The quantification of Theses and Dissertations was also performed by the Nupélia's Sector Library by Universidade Estadual de Maringá (see Figure 2).

To generate the data in Table 1, the articles describing new species of parasites, described for floodplain in the last 37 years and their respective hosts, native and non-native (Ota et al., 2018), were compiled. In the Figure 3 the data of parasite species richness and hosts according to Pavanelli et al. (1997), Takemoto et al. (2009) and Lehun et al. (2020), accumulated richness over time, were used. In the Figure 4, Figure 7B and Figure 8 the parasite and host species richness data according to Lehun et al. (2020) were used.

For the Figures 5 and 6 richness data with taxonomic level of species and genus were used according to Lehun et al. (2020), and plotted in taxonomic groups, since in some groups there is a shortage of material for identification, being genus a high degree of identification and widely accepted for publication, example: parasites of the Hirudinea group. The Figure 7A was used the data of Ota et al. (2018) for host species. In Figure 8 we plotted the hosts with at least ten parasite records at species level, data also according to Lehun et al. (2020). All graphs were produced using the ggplot2 package (Wickham, 2016) in the R Core Team Statistical Software.

3. Results

During the 37 years of monitoring the ichthyoparasites in the upper Paraná River floodplain, 44 new species were described distributed in five large parasite groups for 27 host species, native and non-native to the floodplain (Table 1). The group with the most expressive number of descriptions is the Cestoda class, with three genera and 19 species, followed by the Monogenea class with 16 species. For the groups Flagellata, Myxozoa and Digenea three species were described in each. Among the hosts, those with more species described were *Hemisorubim platyrhynchos* (Valenciennes, 1840) with five species, *Prochilodus lineatus* (Valenciennes, 1836) and *Zungaro jahu* (Ihering, 1898) with four species each.

Allied to the description process, the identification and recording of parasites in hosts has gradually increased over the years (Figure 3). In the first study by Pavanelli et al. (1997) 66 species

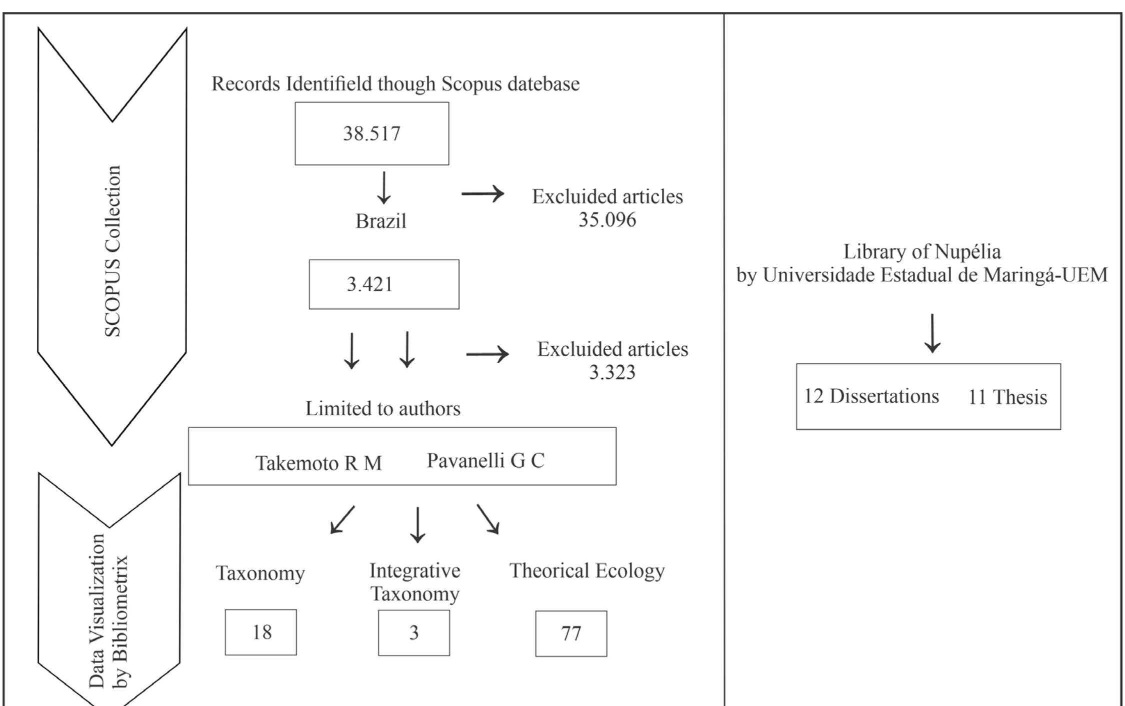

Figure 2. Summary flowchart of the SCOPUS data extraction and the quantification of work done in the 37 years of studies in the upper Paraná River floodplain.

Table 1. Parasite species described in the upper Paraná River floodplain and their respective hosts, during the 37 years of study and monitoring in the Ichthyoparasitology Laboratory of Nupélia.

Group/Species	Host
Flagellata	
Trypanosoma guairaensis Eiras, Rego & Pavanelli, 1989	*Megalancistrus parananus* (Peters, 1881)
Trypanosoma nupelianus Eiras, Rego & Pavanelli, 1990	*Rhinelepis aspera* Spix, Agassiz, 1829
Trypanosoma scrofae Eiras & Pavanelli, 1989	*Prochilodus lineatus* (Valenciennes, 1836)
Myxozoa	
Henneguya paranaensis Eiras, Pavanelli & Takemoto, 2004	*Schizodon borellii* (Boulenger, 1900)*
Henneguya caudicula Eiras, Takemoto & Pavanelli, 2008	*Loricariichthys platymetopon* Isbrücker, Nijssen, 1979*
Henneguya corruscans Eiras, Takemoto & Pavanelli, 2009	*Loricariichthys platymetopon**
Monogenea	
Ameloblastella paranaensis (França, Isaac, Pavanelli & Takemoto, 2003)	*Iheringichthys labrosus* (Lütken, 1874)*
Demidospermus osteomystax Tavernari, Takemoto, Lacerda & Pavanelli, 2010	*Hoplosternum littorale* (Hancock, 1828)
Demidospermus paranaensis Ferrari-Hoeinghaus, Bellay, Takemoto & Pavanelli, 2010	*Loricariichthys platymetopon**
Jainus piava Karling, Bellay, Takemoto & Pavanelli, 2011	*Hoplosternum littorale*
Kritskyia annakohnae Boeger, Tanaka & Pavanelli, 2001	*Serrasalmus maculatus* Kner, 1858, *Serrasalmus marginatus* Valenciennes, 1837*
Kritskyia boegeri, Takemoto,Lizama & Pavanelli, 2002	*Prochilodus lineatus*
Kritskyia eirasi Guidelli, Takemoto & Pavanelli, 2003	*Leporinus friderici* (Bloch, 1794), *Leporinus lacustris* Campos, 1945
Rhinoxenus bulbovaginatus Boeger, Domingues & Pavanelli, 1995	*Salminus brasiliensis* (Cuvier, 1816)
Sciadicleithrum joanae Yamada, Takemoto, Bellay & Pavanelli, 2009	*Crenicichla britskii* Kullander, 1982
Sciadicleithrum kritskyi Bellay, Takemoto, Yamada & Pavanelli, 2009	*Geophagus sveni* Lucinda, Lucena, Assis, 2010*
Sciadicleithrum paranaensis Bellay, Takemoto, Yamada & Pavanelli, 2009	*Geophagus sveni**
Sciadicleithrum satanopercae Yamada, Takemoto, Bellay & Pavanelli, 2009	*Satanoperca* sp.
Tereancistrum curimba Lizama, Takemoto & Pavanelli, 2004	*Prochilodus lineatus*
Tereancistrum paranaensis Karling, Lopes, Takemoto & Pavanelli, 2014	*Schizodon borellii* *
Tereancistrum toksonum Lizama, Takemoto & Pavanelli, 2004	*Prochilodus lineatus*
Trinibaculum rotundus Karling, Lopes, Takemoto & Pavanelli, 2011	*Schizodon borellii**
Digenea	
Dadayius pacupeva Lacerda, Takemoto & Pavanelli, 2003	*Metynnis lippincottianus* (Cope, 1870)*
Kritsky platyrhynchi (Guidelli, Isaac & Pavanelli, 2002)	*Hemisorubim platyrhynchos* (Valenciennes, 1840)
Magnivitellinum corvitellinum Lacerda, Takemoto & Pavanelli, 2009	*Hoplosternum littorale*
Cestoda	
Cangatiella arandasi Pavanelli & Santos, 1990	*Parauchenipterus galeatus* (Linnaeus, 1766)*
Chambriella agostinhoi (Pavanelli & Santos, 1992)	*Zungaro jahu* (Ihering, 1898)
Chambriella itaipuensis (Pavanelli & Rego, 1991)	*Hemisorubim platyrhynchos*
Chambriella paranaensis (Pavanelli & Rego, 1989)	*Hemisorubim platyrhynchos*
Goezeella nupeliensis Pavanelli & Rego, 1991	*Sorubim lima* (Bloch, Schneider, 1801)*
Jauella glandicephala Rego & Pavanelli, 1985	*Zungaro jahu*
Megathylacus brooksi Rego & Pavanelli, 1985	*Zungaro jahu*
Megathylacus travassosi Pavanelli & Santos, 1992	*Pseudoplatystoma corruscans* (Spix, Agassiz, 1829)
Monticellia belavistensis Pavanelli, Machado, Takemoto & Santos, 1994	*Piaractus mesopotamicus* (Holmberg, 1887)
Monticellia loyolai Pavanelli & Santos, 1992	*Pimelodus maculatus* Lacépède, 1803
Nomimoscolex chubbi (Pavanelli & Takemoto, 1995)	*Gymnotus* spp.
Nomimoscolex pertierrae Chambrier, Takemoto & Pavanelli, 2006	*Pseudoplatystoma corruscans*
Nupelia portoricensis Pavanelli & Rego, 1991	*Hemisorubim platyrhynchos*
Proteocephalus serrasalmus Rego & Pavanelli, 1990	*Serrasalmus maculatus*
Proteocephalus vazzolerae Pavanelli & Takemoto, 1995	*Leporinus friderici, Leporinus lacustris*, *Piaractus mesopotamicus*
Spasskyellina mandi Pavanelli & Takemoto, 1996	*Pimelodus ornatus* Kner, 1858*
Spatulifer maringaensis Pavanelli & Rego, 1989	*Hemisorubim platyrhynchos*
Regobothrium microhamulinum Scholz, Takemoto & Kuchta, 2017	*Catathyridium jenynsii* (Günther, 1862)*, *Ageneiosus ucayalensis* Castelnau, 1855*
Travassiella avitellina Rego & Pavanelli, 1987	*Zungaro jahu*

*Are considered non-native fish of the upper Paraná River floodplain, according to Ota et al. (2018).

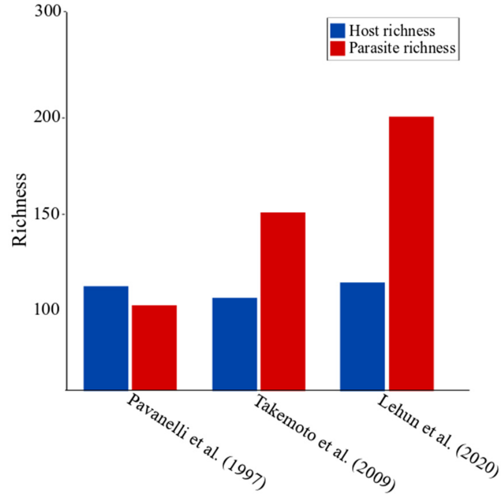

Figure 3. Richness of parasites and hosts in the upper Paraná River floodplain over the years based on the 3 record updating papers.

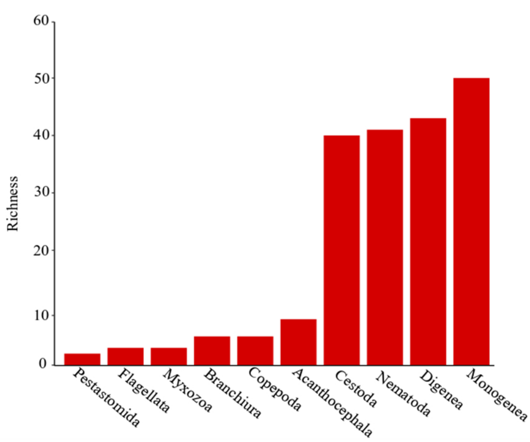

Figure 4. Richness of parasite groups registered in the hosts of the upper Paraná River floodplain in 37 years.

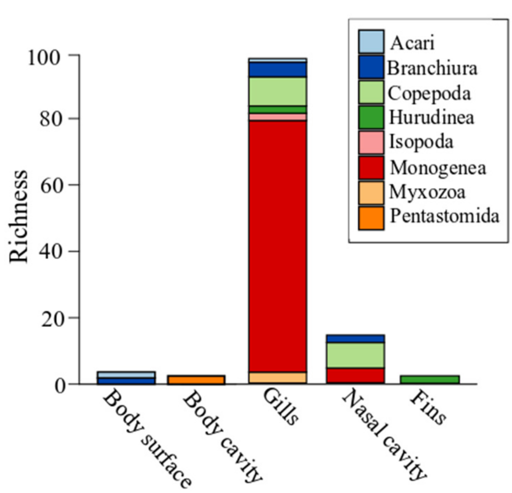

Figure 5. Richness of ectoparasite taxons recorded on the outer surface of the upper Paraná River floodplain hosts.

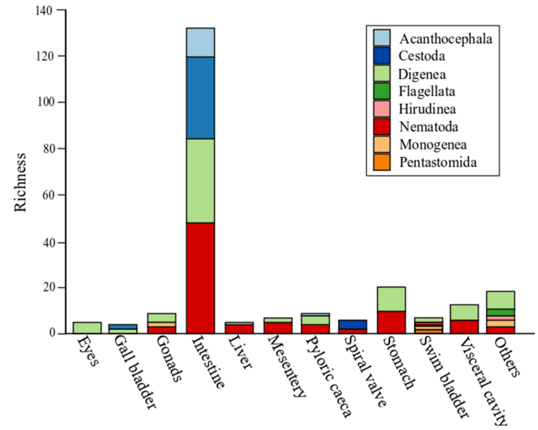

Figure 6. Richness of endoparasites in the internal organs and regions of the hosts in the upper Paraná River floodplain.

of parasites were recorded, a number that increased by 47% in the study by Takemoto et al. (2009) with 138 species. Currently, Lehun et al. (2020) recorded a 68% increase in the number of species, showing a richness of 201 species of parasites. Despite this increase in new species descriptions and new records of parasite-host interaction, a local parasite extinction has also been recorded for floodplain according Karling et al. (2013), who reported the disappearance of the Digenea *Prosthenhystera obesa* Diesing, 1850 in the host *Salminus brasiliensis* (Cuvier 1816) in their study investigating the parasite fauna of this host 10 years after the construction of the Porto Primavera Hydroelectric dam.

Among the ten groups of parasites presented in Figure 4, the Monogenea class presented the greatest richness, with 50 species identified and registered. Digenea, Nematoda and Cestoda presented similar richness values. The Platyhelminthes phylum is currently the largest in numbers of species, with three groups, Monogenea, Digenea and Cestoda, which together present 133 species recorded for floodplain. The phylum Arthropoda, also with three groups, Branchiura, Copepoda and Pentastomide, together have only 13 species recorded.

In the floodplain, eight groups of ectoparasites are registered: Myxozoa, Monogenea, Branchiura, Copepoda, Isopoda, Pentastomide, Hirudinea and Acari. In Figure 5 it is shown that the site with the highest rate of ectoparasitic infection is the gills, presenting 89 taxons, a number that is higher than the other infection sites.

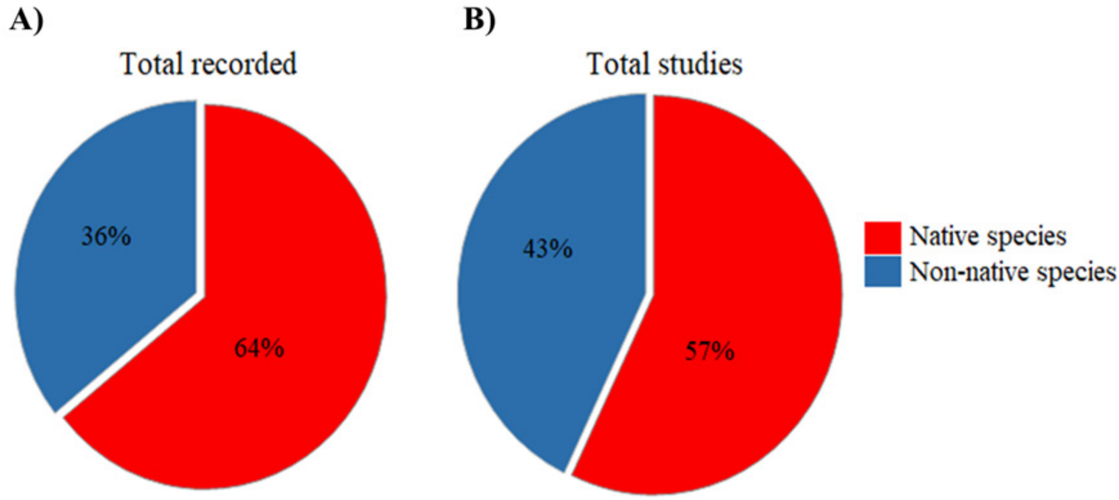

Figure 7. (A) Percentage of native and non-native fish registered in the upper Parana River floodplain according to Ota et al. (2018); (B) Percentage of native and non-native hosts in the floodplain (Ota et al., 2018) studied by the Ichthyoparasitology Laboratory.

Regarding endoparasites, eight groups are registered, Flagellata, Digenea, Cestoda, Nematoda, Acanthocephala, Monogenea, Hirudinea and Pentastomide (Figure 6). Most of the endoparasite richness is concentrated in the intestine of the hosts, with 138 species of parasites recorded. This high richness of species can be explained by the fact that some parasite groups occur only in this site, such as the Acanthocephala and most of the Nematoda.

The invasion by non-native fish of the floodplain is a fact that has been accentuated in recent years. In Figure 7A, we can observe that approximately 45% of the fish species registered for the upper Paraná River floodplain are considered non-native, and in Figure 7B, we highlight that most of the studies are with native species, but a large number of the studies are with non-native fish species

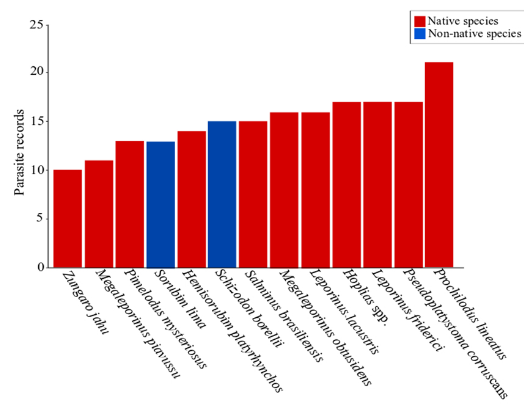

Figure 8. Richness of parasites for the hosts with the most records.

Among the hosts with the highest numbers of parasite registration (Figure 8), two species are non-native *Sorubim lima* and *Schizodon borellii* and all the hosts that register the greatest richness of parasites are also fish appreciated in human consumption and of commercial importance. The host *Prochilodus lineatus* is the fish species with the highest number of parasite records in the floodplain, presenting about 20 species of parasites belonging to different groups.

4. Discussion

In the 37-year period of studies in the upper Paraná River floodplain, 44 new species of parasites belonging to different groups were described for 27 species of fish of different orders. Currently more than 80 hosts have their parasite fauna registered. This increase in knowledge of species richness is due to the increase in the number of studies conducted in recent years, as long-term studies on parasite-host interaction are generally rare in parasitology, although of crucial importance for a better understanding of many aspects of parasite ecology (Kennedy, 1993; 2009).

For the knowledge of local biodiversity, taxonomy is an historically important science, contributing to the understanding of the existing diversity and understanding its evolution (Bremer et al., 1990; Poulin et al., 2020), and together with ecological studies, it provides data from observations of natural variations in populations, communities and ecosystems (Symstad et al., 2003), thus complementing the knowledge of the structure of these environments. Our work shows that the description of parasite species was very expressive in the floodplain, mainly for monogeneans and cestodes (Table 1).

Taxonomic studies with the Cestoda and Monogenea classes were carried out during the first years of study, and address the so-called classic taxonomy, based on the morphological characteristics of the species (Rego & Pavanelli, 1985; Eiras et al., 1986). Over the years, the advance of technology and the modernization of science, allowed studies of integrative taxonomy, which unites morphology and molecular biology, to be carried out, advancing in the molecular characterization of the species, allowing studies of coevolution and specificity in the host parasite relationship (Gasques et al., 2016; Scholz, Takemoto & Kuchta, 2017; Graça et al., 2018; Franceschini et al., 2018).

The number of species recorded has increased in recent years (Figure 2). According to Pavanelli et al. (1997) and Takemoto et al. (2009) the chemical and physical variables of water (dissolved oxygen, temperature and water flow), can contribute to the emergence and installation of parasites, besides the great availability of hosts that the floodplain presents. Thus, favorable hydrological conditions, adequate environmental variables and possibilities of different hosts are fundamental characteristics for parasites to complete their life cycle, and in the floodplain, the mobility of parasites between hosts and in the environment is facilitated by the hydrometric variation, which according to Thomaz et al. (2007), increases in the months of flooding connecting the environments in the floodplain.

Among the registered groups, Monogenea, Digenea, Nematoda and Cestoda presented the greatest richness of species and this demonstrates a direct relation with the parasitic habit, because the gills and the intestine presented the highest infection rates among the hosts. The differences between ecto and endoparasites can be explained by two related aspects: (I) due to low and high specificity; and (II) differences in selection pressure to maximize cross-fertilization of parasites that occur in the final host (Brown et al., 2001). Most endoparasites (Acanthocephala, Cestoda, Digenea and Nematoda) belong to groups known for their low specificity in larval stages (Bellay et al., 2013) and infect definitive hosts (or some intermediate hosts) mainly by food intake (Lima et al. 2016), and have similar morphophysiological and ecological characteristics, which allow them to be exposed to peristaltic movements and gastric juices of the host (Bush et al., 2001; Bellay et al., 2020), and when adults subsist only in this site.

Ectoparasites consist mainly of monogenetics, recognized for their high specificity (Poulin, 1992; Dobson et al., 2008). Their transmission in hosts occurs through active search (Pariselle et al., 2011) and because they occupy microhabitats outside the host body, they are more susceptible to environmental variations. According to Bellay et al. (2020), studies based on host interaction networks demonstrate that in large aquatic water bodies, ectoparasites tend to be more sensitive to the extinction of host species, and have their existence and permanence in the environment negatively affected, that is, in the same networks of interactions extinctions are greater of ectoparasites than of endoparasites when there is the extinction of some host.

A single fish can be an intermediate and definitive host, housing several groups of parasites and several infection sites (Takemoto et al., 2009), as shown in Figures 4 and 5. An example worth considering is the fish *Prochilodus lineatus*, which in this work presented the largest number of records (Figure 7). Its diet is composed mainly of detritus, presents great body size and performs great migrations for reproduction (Castro & Vari, 2004; Benedito et al., 2018), which can favor the acquisition of parasites, since, the highest degree of parasitism occurs when *Prochilodus lineatus* becomes adult (Lizama et al., 2005). Among the non-native fishes of the plain, *Sorubim lima* and *Schizodon borellii*, presented greater register of parasites, however the interactions of the parasites in new hosts and habitats, is still little known.

According to Lacerda et al. (2013), during migration to new habitats, fish may or may not lose their parasites, acquire native fish parasites, or introduced parasites may be able to colonize fish from the new region. Generalist parasites are found in native and non-native hosts, regardless of the trophic position of the host, as is the case with the metacaries of *Austrodiplostomum compactum* (Lutz, 1928), found in the eyes of different fish species in the floodplain (Lehun et al., 2020).

In this sense, studies of parasite manipulation have been developed and bringing discoveries that influence much more than ichthyoparasitology, but the whole balance of the aquatic ecosystem of the floodplain. In a study conducted by Affonso et al. (2017), it was demonstrated that diplostomideos (metacercaries) when infecting their intermediate host (*Satanoperca pappaterra*), migrate to the eyes, impairing vision and changing anti-predator behavior, leaving hosts more susceptible to predation by piscivorous birds, increasing the chances of the parasite completing its life cycle and collaborating to the control of this non-native fish species of the floodplain. Besides anti-predator behavior, it is also known that the host once parasitized by *Clinostomum* (metacercariae) has its life history characteristics negatively affected, so if it is not predated, its fitness is likely to be negatively affected by difficulty in foraging (Nicola et al., 2020).

With the knowledge of biodiversity and general patterns of host parasite interaction that occur in the floodplain, other areas of ecology studies were possible to be reached, such as ecotoxicology. A recent study conducted on the floodplain with two species of Acanthocephala corroborated with general ideas that parasites can be used as bioindicators (Lehun et al., 2021), and not only because of their presence or absence, but also because of their potential for bioaccumulation of trace metals, which in the study even proved to be greater than their hosts (Duarte et al., 2020), demonstrating direct response of parasites in relation to anthropogenic impacts.

Anthropogenic environmental impacts also modify the ichthyofauna (Audry et al., 2004; Quinatto et al., 2018), among them the damming of rivers and construction of hydroelectric plants promote changes in lotic to lentic environments and consequent reduction in fish diversity (Agostinho et al., 2008; Agostinho et al., 2016), moreover, occur simultaneously, introduction and establishment of non-native species (Vitule et al., 2009, Garcia et al., 2019). In the upper Paraná River floodplain, 36% of the records on ichthyofauna are with non-native species (Figure 7A) following with similar proportions, 43% of the studies on ichthyoparasitology (Figure 7B). This similar proportion of records and studies conducted with native and non-native species in the upper Paraná River floodplain can be explained by the success and establishment of these introduced species as is the case of *Cichla* sp. (Pelicice & Agostinho, 2009; Gasques et al., 2014) and the need for information on parasitic fauna in these new environments (Pavanelli et al., 2013). This result reinforces the presence of non-natives and the importance of long-term management and monitoring plans, as well as studies addressing the relation parasite, host, environment.

An important way to mitigate anthropogenic activities including the introduction of non-native species is the creation of permanent preservation areas, parks and legal reserves. Protected and preserved areas reduce the impact of anthropogenic disturbance on communities (Pineda et al., 2020), protecting and conserving local biodiversity. Thus, the studies developed on the plains and the reports resulting from these studies were responsible for supporting the legal documents for the creation of three environmental protection areas (APA) in the archipelago of Ilha Grande, in municipals of Altônia (275.23 Km^2; June/1994), São Jorge do Patrocínio (217.11 Km^2; June/1994) and Vila Alta (195.67 Km^2; February/1993) (Agostinho & Zalewski, 1996). Among these, other measures were adopted such as the removal of cattle from the Paraná River islands and the creation of the Parque Estadual das Varzeas do Rio Ivinhema in 1998, with a preservation area of 73,345.15 hectares located in the upper Paraná River floodplain.

Studies in the upper Paraná River floodplain demonstrate a broad knowledge of local parasitic diversity. Over the 37 years, the increase of parasite species descriptions has been observed. This fact may indicate that the floodplain offers favorable conditions for the maintenance and installation of these organisms, despite the anthropic environmental alterations. Knowing the dynamics of heterogeneous environments such as the floodplains is only possible through long-term studies (Brito et al., 2020), because the interactions between species are complex and require time for understanding, such as the life cycle of a parasite or the factors that lead it to recognize a new host. In times where the environment shrinks every day, it is of paramount importance to care for and preserve the floodplains to maintain biodiversity.

Currently biodiversity is undergoing mass extinction in record time, where aquatic ecosystems are intensely affected and much of the biodiversity is being extinguished before it is even known. In order to preserve any species, it is necessary first to know its natural environment, as well as the ecological interactions in which it participates. In this scenario the taxonomy, systematic and ecology are crisis sciences, added to long term studies because this way it is possible to create safe bases of knowledge, monitoring, management and conservation of biodiversity. In this way, studies of ichthyoparasitology are necessary and continuous.

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