



Community structure of metazoan parasites of *Trichiurus lepturus* (Perciformes, Trichiuridae) from Ubatuba, Southwestern Atlantic Ocean, Brazil

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ABSTRACT. This study aimed to evaluate the community structure of metazoan parasites of *Trichiurus lepturus* from Ubatuba, Brazil. Fifty fish were collected in February 2008. Our statistical approach consisted in evidencing the most interesting infrapopulations, in order to try to understand the relationship between the variables regulating them. This analysis was based on a Poisson generalized linear model (GLM) developed with selection of variables using the corrected Akaike Information Criterion (AICc) and AIC weight. Larvae of Anisakidae and *Lecithochirium microstomum* seems to play an important role on this host-parasite system and their abundances were influenced by the ontogenetic shift in feeding of the hosts. Changes in characteristics of hosts included a negative relationship between increased abundance of anisakids' larvae and reduction in host weight. Gender biases were statistically consistent, but further long-term research is required to confirm them. Finally, we show the challenges that may be addressed in future research.

Keywords: South America, marine, parasite ecology.

Estrutura da comunidade de parasitos metazoários de *Trichiurus lepturus* (Perciformes, Trichiuridae) de Ubatuba, Oceano Atlântico Sudoeste, Brasil

RESUMO. O objetivo deste estudo foi avaliar a estrutura da comunidade de parasitos metazoários de *Trichiurus lepturus* de Ubatuba, Brasil. Em fevereiro de 2008, foram coletados 50 peixes. Nossa abordagem estatística consistiu em evidenciar as infrapopulações mais interessantes, para posteriormente tentar entender as relações entre as variáveis que as regulam. Essa análise foi baseada em um modelo linear generalizado (MLG), família Poisson, desenvolvido com seleção de variáveis usando o Akaike Information Criteria corrigido (AICc) e o peso de AIC. Larvas de Anisakidae e *Lecithochirium microstomum* parecem desempenhar importante papel nesse sistema parasito-hospedeiro e suas abundâncias foram influenciadas pela alteração ontogenética na alimentação dos hospedeiros. Alterações nas características dos hospedeiros parecem ocorrer com uma relação negativa entre o aumento da abundância de larvas de anisquídeos e a diminuição do peso dos hospedeiros. Vieses sexuais foram estatisticamente consistentes, porém pesquisas adicionais de longo prazo são necessárias para confirmá-los. Com isto, exibimos desafios que podem ser caminhos para futuras pesquisas.

Palavras-chave: América do Sul, marinho, ecologia de parasitos.

Introduction

The cutlassfish or largehead hairtail *Trichiurus lepturus* Linnaeus, 1758 is a marine fish widely distributed throughout the world (FAO, 2005; FROESE; PAULY, 2013). It is among the ten top species that contribute most to the world total marine capture fisheries production (FAO, 2005). Among the fisheries resources of the southeastern and southern Brazil, this species has assumed a growing importance, although there is no directed fishery for its exploitation (CERGOLE et al., 2005;

HAIMOVICI, 1997; NAKATANI et al., 1980). Despite of this fact, the high exploitation of *T. lepturus* has raised concerns in some countries (CERGOLE et al., 2005) and in the Northwest Pacific Ocean was estimated to be overexploited (FAO, 2012). Additionally, the lack of interest of some Brazilian markets on this species makes individuals, especially juveniles, to be largely discarded in various fisheries (CERGOLE et al., 2005).

Fishing and other human impacts can influence the marine community structure reducing the abundance of parasites (WOOD et al., 2013).

Considering that parasites play an important role in the evolution of hosts by influencing host traits (POULIN; MORAND, 2004), revealing these changes is important to try to understand the nature of the processes that can be ruled by parasitism.

Studies on the parasites of *T. lepturus* have been conducted since the 70's in the Brazilian coastal zone (BARROS; AMATO, 1993; BORGES et al., 2012; BOXSHALL; MONTÚ, 1997; CARVALHO; LUQUE, 2009, 2011, 2012; CAVALCANTI et al., 2012; FREITAS; GOMES, 1971; FREITAS; SANTOS, 1971; LUQUE et al., 1998; ROHDE et al., 1995; SÃO CLEMENTE et al., 1995; SILVA et al., 2000; VICENTE; SANTOS, 1974; WALLET; KOHN, 1987;). Some of these researches involved taxonomic aspects and others had a zoonotic or ecological approach.

In Ubatuba, São Paulo State, some studies were carried out on fish parasites (CARVALHO, 1951; SANTOS et al., 2001; SANCHES, 2008). Our study aimed to evaluate the community structure of metazoan parasites of *T. lepturus* from the Ubatuba Bay, São Paulo State, Brazil.

Material and methods

Fifty fishes from Ubatuba, SP, were examined including 25 females (total length = 102.24 ± 3.9 cm; weight = 607.4 ± 79.3 g); 8 males (tl = 97.37 ± 4.3 , w = 529 ± 70.1) and 17 of undetermined sex (tl = 96.82 ± 7.6 ; w = 530.65 ± 132.48), all collected by professional fisherman in February 2008. Fish were transported to Laboratório de Parasitologia da Universidade de Taubaté (IBB-UNITAU) for examination. Individuals were identified, according to Figueiredo and Menezes (2000), weighed, measured and sexed, according to Vazzoler (1996).

The parasites recovered were prepared for identification according to Amato et al. (1991), except the crustaceans that were fixed in 70% ethanol and mounted on temporary glass slides with lactic acid. The identification of parasites was based on Boxshall and Montu (1997), Kohn and Cohen (2007), Luque et al. (2011) and Carvalho and Luque (2012). Parasites were deposited on the Collection of Platyhelminthes (ZUEC-PLA), Acanthocephala (ZUEC-ACA), Nematoda (ZUEC-NMA) and Collection of Crustacea (ZUEC-CRU), Museu de Zoologia da Universidade Estadual de Campinas – UNICAMP.

The length and weight of female and male hosts were compared through Student *t*-test (*t*) with confidence interval of 95%. When individual of

undetermined sex were included, an Analysis of Variance (ANOVA) was applied, followed by Tukey's test (Q). All values of total length and weight of hosts were log-transformed [$\log_{10}(x + 1)$] (ZAR, 1999) for this analysis. The quantitative descriptors of all parasites were calculated according to Bush et al. (1997). Differences in the parasite abundance at community level were tested by ANOVA followed by an Tukey test (Q). The frequency of dominance and relative dominance were evaluated according to Rohde et al. (1995).

Pearson's correlation was applied to evaluate the correlation between the total length and weight of hosts with the abundance and intensity of infection. The correlation between the total length and weight of hosts with the prevalence of infection was tested by the Spearman's correlation. For these tests, we considered the component populations with at least 10% of prevalence of infection (BUSH et al., 1990). For these analyses, all data were previously log-transformed [$\log_{10}(x + 1)$] (ZAR, 1999).

A Poisson generalized linear model (GLM) was used to try to understand the relationship between the variables (FARAWAY, 2006). A set of 14 Poisson GLM was developed for component populations that presented significant correlations in the previous analysis. We sought to find the best set of variables that explain the resources (host sex, length and weight) and the space sharing (co-occurrence with other parasites including those with <10% prevalence) required by these parasites. The variable hosts' sex was transformed into a categorical variable, and the undetermined sex was taken as a baseline or reference parameter. Models were ranked with the corrected Akaike's information criterion (AICc) and AICc weight, using the package AICcmodavg implemented on R 2.15.2 (R CORE TEAM, 2012; MAZEROLLE, 2013). For all analyses involving parasites we considered significant the values with $p < 0.05$.

Results

Females and males showed differences on total length ($t = 2.88$; $p = 0.015$) and weight ($t = 2.662$; $p = 0.021$), with higher values for females. However, when females, males and fishes of undetermined sex were analyzed together, females were only larger than undetermined sex fish ($Q = -0.056$; $p = 0.006$) and heavier than males ($Q = 0.156$; $p = 0.019$).

Altogether 31,654 parasites were collected, belonging to nine higher taxa, including one acanthocephalan; one digenean; three monogeneans; two cestodes, plus the cysts of Trypanorhyncha; larvae of Anisakidae; and two species of copepods (Table 1).

The most prevalent species of the parasite community was *Lecithochirium microstomum* Chandler, 1935. Larvae of Anisakidae and the metacestode *Scolex pleuronectis* Müller, 1758 represented, respectively, the second and third most prevalent taxon (Table 1).

On the component community evaluated, *L. microstomum* was the most abundant species ($F = 493$; $p < 0.05$) (Tables 1 and 2) and the dominant component population (frequency of dominance = 50; relative dominance = 0.15 ± 0.06), compared with relative dominance of larvae of Anisakidae (0.002 ± 0.001), which were the second most abundant component population.

The abundance of Anisakidae larvae ($pp = 0.3063581$; $p = 0.03623$) and cysts of Trypanorhyncha ($pp = 0.3262512$; $p = 0.02215$) were positively correlated with host length. The host length was also a positive predictor of infection intensity for Anisakidae larvae. The weight of hosts has positively influenced the abundance and intensity of infection of *L. microstomum* ($pp = 0.328113$; $p = 0.0228$). The prevalence of cysts of Trypanorhyncha was also positively affected by the weight of hosts ($ps = 0.9549937$; $p = 0.0008055$).

For *L. microstomum*, the model with the highest weight included all variables ($\Delta AICc$ 0.00, Table 3). The same occurred for Anisakidae, but for Trypanorhyncha cysts, the best model was the one containing a set of five among the 13 variables considered. The $AICc$ of the best model for *L. microstomum* was substantially different from the model with the lowest weight ($\Delta AICc$ value between the best and worst model = 1035.32). This was also observed for the best model for Anisakidae ($\Delta AICc$ value between the best and worst model = 152.96) and Trypanorhyncha ($\Delta AICc$ value between the best and worst model = 37.74), however with a smaller difference.

For the abundance of *L. microstomum* and Anisakidae larvae, only *P. guanabarensis* and *M. uruguayensis* had no significant influences (Table 4). While for cysts of Trypanorhyncha, only male hosts and abundance of Anisakidae were significant. Unlike *L. microstomum*, the total length and weight of hosts contributed to increasing and decreasing ($p < 0.05$), respectively, the abundance of Anisakidae.

Table 1. Prevalence, intensity range, mean abundance, mean intensity and site of infection of metazoan parasites of *Trichiurus lepturus* from Ubatuba, southwestern Atlantic Ocean, Brazil.

Parasites	Prevalence (%)	Intensity Range	Mean Abundance $\pm$ SD	Mean Intensity $\pm$ SD	Site
Acanthocephala					
<i>Polymorphus</i> sp. (cystacanth) ZUEC-ACA 6–10	56	0–15	2.2 ± 3	4 ± 3	liver, intestine
Digenea					
<i>Lecithochirium microstomum</i> ZUEC-PLA 40–41	100	31–1111	557.4 ± 243.5	557.4 ± 243.5	gills, stomach, intestine
Monogenea					
Capsalidae gen. sp. ZUEC-PLA 32	2	0–1	0.02 ± 0.14	1	body surface
<i>Pseudempleurosoma guanabarensis</i> ZUEC-PLA 33–39	44	0–5	0.9 ± 1.3	1.9 ± 1.25	oesophagus
<i>Octoplectanocotyla travassosi</i> ZUEC-PLA 29–31	10	0–2	0.12 ± 0.4	1.2 ± 0.45	gills
Cestoda					
<i>Callitetrarhynchus gracilis</i> (plerocercoid) ZUEC-PLA 42	2	0–1	0.02 ± 0.14	1	stomach
<i>Scolex pleuronectis</i> (metacestode) ZUEC-PLA 43–55	86	0–182	20 ± 30.4	23.8 ± 31.8	intestine
Trypanorhyncha (cysts) ZUEC-PLA 25–28	30	0–12	1.4 ± 3	4.8 ± 3.5	muscle
Nematoda					
Anisakidae (larvae) ZUEC-NMA 14–17	100	5–112	50.7 ± 26	50.7 ± 26	stomach, liver, intestine
Copepoda					
<i>Bomolochus</i> sp. ZUEC-CRU 698	2	0–1	0.02 ± 0.14	1	gills
<i>Metacaligus uruguayensis</i> ZUEC-CRU 699–701	14	0–3	0.2 ± 0.6	1.4 ± 0.8	gills, eyes

Table 2. Tukey's test (Q) applied to test differences in abundance of metazoan parasites of *Trichiurus lepturus* from Ubatuba, southwestern Atlantic Ocean, Brazil.

Parasites	Q	p-value	Parasites	Q	p-value
<i>L. microstomum</i> -Anisakidae	2401163	0.000*	<i>S. pleuronectis</i> - <i>O. travassosi</i>	2171476	0.000*
<i>L. microstomum</i> - <i>M. uruguayensis</i>	-6068919	0.000*	<i>S. pleuronectis</i> - <i>P. guanabarensis</i>	1802908	0.000*
<i>L. microstomum</i> - <i>O. travassosi</i>	-6110508	0.000*	<i>S. pleuronectis</i> - <i>Polymorphus</i> sp.	1423188	0.000*
<i>L. microstomum</i> - <i>P. guanabarensis</i>	-5741940	0.000*	<i>S. pleuronectis</i> -Trypanorhyncha	1423188	0.000*
<i>L. microstomum</i> - <i>Polymorphus</i> sp.	-5362220	0.000*	<i>Polymorphus</i> sp.- <i>M. uruguayensis</i>	-1771568	0.000*
<i>L. microstomum</i> - <i>S. pleuronectis</i>	-3939032	0.000*	<i>Polymorphus</i> sp.- <i>O. travassosi</i>	706699,5	0.000*
<i>L. microstomum</i> -Trypanorhyncha	-5710600	0.000*	<i>Polymorphus</i> sp.- <i>P. guanabarensis</i>	379719,9	0.106
Anisakidae- <i>M. uruguayensis</i>	-3667757	0.000*	<i>Polymorphus</i> sp.-Trypanorhyncha	-348379,9	0.194
Anisakidae- <i>O. travassosi</i>	-3709346	0.000*	<i>P. guanabarensis</i> - <i>M. uruguayensis</i>	326979,6	0.277
Anisakidae- <i>P. guanabarensis</i>	-3340777	0.000*	<i>P. guanabarensis</i> - <i>O. travassosi</i>	368568,4	0.133
Anisakidae- <i>Polymorphus</i> sp.	-2961057	0.000*	<i>P. guanabarensis</i> -Trypanorhyncha	31339,98	1.000
Anisakidae- <i>S. pleuronectis</i>	-1537869	0.000*	Trypanorhyncha- <i>M. uruguayensis</i>	358319,6	0.162
Anisakidae-Trypanorhyncha	-3309437	0.000*	Trypanorhyncha- <i>O. travassosi</i>	399908,4	0.0692
<i>S. pleuronectis</i> - <i>M. uruguayensis</i>	2129887	0.000*	<i>O. travassosi</i> - <i>M. uruguayensis</i>	-41588,83	0.999

*statistically significant values at 5%.

Table 3. Comparison of 14 Poisson regression using host traits and abundance of metazoan parasites of *Trichiurus lepturus* from the Ubatuba Bay, southwestern Atlantic Ocean, Brazil.

<i>L. microstomum</i>			Anisakidae			Trypanorhyncha		
Model ¹	ΔAICc	Weight	Model ¹	ΔAICc	Weight	Model ¹	ΔAICc	Weight
Tl+W+Sx+A+S+P+T+Pg+O+M+C+Cg+B	0.00	1	Tl+W+Sx+L+S+P+T+P	0.00	0.9	Tl+W+Sx+L+A	0.00	0.65
Tl+W+Sx+A+S+P+T+Pg+O+M+C+Cg	72.38	0	g+O +M+C+Cg+B	4.46	0.1	Tl+W+Sx+L+A+S	1.90	0.25
Tl+W+A+S+P+T+Pg+O+M+C+Cg+B	278.08	0	Tl+W+Sx+L+S+P+T+P	36.38	0.0	Tl+W+Sx+L+A+S+P	4.78	0.06
Tl+W+Sx+A+S+P+T+Pg+O+M+C	422.40	0	g+O +M+C+Cg	51.98	0.0	Tl+W+Sx+L+A+S+P+Pg+	7.41	0.02
Tl+W+Sx+A+S+P+T+Pg+O	583.23	0	Tl+W+Sx+L+S+P+T+P	78.60	0.0	Tl+W+Sx+L+A+S+P+Pg+O	8.51	0.01
Tl+W+Sx+A+S+P+T+Pg+O+M	580.34	0	g+O	79.01	0.0	Tl+W+Sx	9.19	0.01
Tl+W+Sx+A+S+P+T+Pg	642.87	0	Tl+W+Sx+L+S+P+T+P	82.48	0.0	Tl+W+Sx+L	11.89	0.00
Tl+W+Sx+A+S+P	648.22	0	g+O+M	82.58	0.0	Tl+W+Sx+L+A+S+P+Pg+O+M	12.63	0.00
Tl+W+Sx+A+S+P+T	645.18	0	Tl+W+Sx+L+S+P+T+P	82.58	0.0	M	15.60	0.00
Tl+W+Sx+A+S	670.35	0	Sx+L+S+P+T+Pg+O+M	114.72	0.0	C+Cg+B	16.23	0.00
Sx+A+S+P+T+Pg+O+M+C+Cg+B	676.41	0	+C+Cg+B	116.47	0.0	Tl+W+Sx+L+A+S+P+Pg+O+M+C	17.41	0.00
Tl+W+Sx+A	690.60	0	L+S+P+T+Pg+O+M+C	119.42	0.0	M+C	20.84	0.00
Tl+W+Sx	828.69	0	Tl+W+Sx+L+S+P	132.12	0.0	M+C+Cg	36.15	0.00
A+S+P+T+Pg+O+M+C+Cg+B	1035.32	0	Tl+W+Sx+L	136.12	0.0	M+C+Cg+B	37.74	0.00
			Tl+W+Sx	152.96	0.0	B		

¹The best model showed the greatest weight and lowest AICc value. Model variables: Tl, total length; W, weight; Sx, Sex; L, *L. microstomum*; A, Anisakidae; S, *S. pleuronectis*; P, *Polymorphus* sp.; T, Trypanorhyncha; Pg, *P. guanabarensis*; O, *O. travassosi*; M, *M. uruguayensis*; C, Capsalidae; Cg, *C. gracilis*; and B, *Bomolochus* sp.

Table 4. Beta parameters (β) and *p* value (*p*) for the Poisson GLM using host traits and abundance of metazoan parasites of *Trichiurus lepturus* from the Ubatuba Bay, southwestern Atlantic Ocean, Brazil. The most parsimonious model selected by the corrected Akaike information criterion (AICc) and AICc weight.

Variables	<i>L. microstomum</i>		Anisakidae		Trypanorhyncha	
	β	<i>p</i>	β	<i>p</i>	β	<i>p</i>
Total length	-0.139	< 2e-16*	0.1825581	< 2e-16*	1.556e-01	0.053
Weight	0.009	< 2e-16*	-0.0104819	< 2e-16*	-8.478e-04	0.854
Sex-Female	0.076	7.93e-05*	0.1730040	0.010502*	5.396e-01	0.111
Sex-Male	-0.310	< 2e-16*	0.2983391	0.000198*	1.586e+00	7.8e-05*
<i>L. microstomum</i>	-	-	0.0005058	5.07e-07*	3.869e-05	0.951
Anisakidae	0.005	< 2e-16*	-	-	-2.185e-02	0.000*
<i>S. pleuronectis</i>	0.001	0.005*	0.0015769	0.044906*	-	-
<i>Polymorphus</i> sp.	0.021	< 2e-16*	-0.0274732	0.002360*	-	-
Trypanorhyncha	-0.007	0.00148*	-0.0295173	0.001843*	-	-
<i>P. guanabarensis</i>	0.003	0.55694	0.0069460	0.719189	-	-
<i>O. travassosi</i>	0.357	< 2e-16*	-0.3560145	4.92e-06*	-	-
<i>M. uruguayensis</i>	-0.008	0.56726	0.0518914	0.198804	-	-
Capsalidae gen. sp.	-0.803	< 2e-16*	-1.5404895	2.49e-06*	-	-
<i>C. gracilis</i>	-1.081	< 2e-16*	0.7861033	4.36e-08*	-	-
<i>Bomolochus</i> sp.	-0.382	< 2e-16*	0.7660862	2.38e-12*	-	-

*statistically significant values on 5% level.

Discussion

The component community of metazoan parasites of *T. lepturus* can vary according to its geographic distribution (CARVALHO; LUQUE, 2011; CAVALCANTI et al., 2012; HO; LIN, 2002; JAKOB; PALM, 2006; SILVA et al., 2000). Some parasite species of *T. lepturus* were recorded in a single geographic locality, such as digeneans, monogeneans, cestodes, nematodes and copepods in Indonesia (JAKOB; PALM, 2006), Taiwan (HO; LIN, 2002) and Brazil (CARVALHO; LUQUE, 2011; CAVALCANTI et al., 2012). Simultaneously,

the abundance of these parasites can also vary. But in Brazilian waters, *L. microstomum* has exhibited a similar trend of infection in *T. lepturus*. This broadly distributed species (FERNANDES et al., 2009) was more abundant and the dominant infrapopulation of the component community of *T. lepturus*, as previously reported (CARVALHO; LUQUE, 2011; SILVA et al., 2000) and seems to play a key role on this host-parasite system, like larvae of Anisakidae.

The ontogenetic changes in feeding habits of *T. lepturus* have been documented in Brazil (HAIMOVICI et al., 2008; MARTINS et al., 2005). These shifts can be the driver of differences

observed in abundance of some parasites. The population of *T. lepturus* examined was composed by sub-adults and adults, according to Martins et al. (2005). In our analysis, smaller and heavier females were more abundantly parasitized by *L. microstomum*, while larger and lighter males exhibited an increased abundance of infection by Anisakidae (Table 4).

Juveniles and sub-adults of *T. lepturus* feed more intensely than the adults (MARTINS et al., 2005). This finding can partially support the positive relationship between the weight of *T. lepturus* and intensity of *L. microstomum* and the negative relationship between the weight of *T. lepturus* and intensity of Anisakidae larvae, if we consider that, smaller and heavier fish tend to be younger, while larger and lighter fish, adults. However, the length of *T. lepturus* was the most powerful and positive explanatory variable of its weight (Adjusted R-squared: 0.9029; $p < 0.05$, results not shown), but then, why the results have lead to the interpretation that larger fish were lighter and why each group of parasites seems to require an optimality regarding the host traits?

Larvae of Anisakidae can be transmitted to *T. lepturus* through ingestion of intermediate or paratenic hosts. These potential hosts can be small fish, such as *Engraulis anchoita* Hubbs and Marini, 1935, as registered by Timi (2003) in Argentina. This is an oceanodromous fish (FROESE; PAULY, 2013), reported in the Brazilian continental shelf accompanied by *T. lepturus* (CERGOLE et al., 2005) and is one of the selected food items of sub-adults and adults of *T. lepturus* (MARTINS et al., 2005). However, some crustaceans could play this role (MCCLELLAND, 2005). Silva et al. (2000) hypothesized that *L. microstomum* can be transmitted to *T. lepturus* through ingestion of decapod crustaceans, the food predominantly ingested by juvenile fish (MARTINS et al., 2005).

It has been established that some parasites can affect physiological systems of fishes, leading to increased metabolic rates (BINNING et al., 2013; CAREAU et al., 2010), body weight loss (BOOTH et al., 1993), and longer time spent on foraging, which increases the predation risk (GODIN; SPROUL, 1988). In the present research, larvae of Anisakidae were predominantly recovered from the body cavity, inhabiting the surface of internal organs. This type of parasite is more associated with increased exposure of vertebrates to predators (LAFFERTY; SHAW, 2013) and this relationship is particularly known for larval sealworm (MCCLELLAND, 2005).

We believe that larvae of Anisakidae are transmitted to *T. lepturus* by both crustaceans and small fish. The intense consumption of these food items by smaller fish has as consequence the increase in weight of fish and in abundance of Anisakidae and *L. microstomum* (Table 4), since some parasites can be favored by infections, because they suppress the immune system of hosts (SCHMID-HEMPEL, 2011). According to the ontogenetic growth, the increasingly abundant larvae of Anisakidae probably stimulate *T. lepturus* to forage, causing body weight loss and exposing them to predation by definitive hosts of anisakids, such as elasmobranchs and cetaceans. If this situation occurs, it may contribute to the coexistence of species, which are potential competitors due to their feeding habits. This is especially the case of the potential dietary overlap between *T. lepturus* and *Pontoporia blainvillei* (BITTAR; DI BENEDITTO, 2009), an endangered cetacean species (DI BENEDITTO et al., 2010).

Gender biases on parasitism have been documented in several host-parasite systems (DUNEAU et al., 2012; FERRARI et al., 2007; GREAR et al., 2012; SCHMID-HEMPEL, 2011) and this is also true for fish (REIMCHEN; NOSIL, 2001; SCHMID-HEMPEL, 2011). In the present paper, a statistical significance was revealed for the abundances of cysts of Trypanorhyncha, *L. microstomum* and anisakids (Table 4). In the relationship between host sex and abundance of *L. microstomum*, the significance observed for males and females, were respectively, negative and positive, and so, females are more prone than males to acquire more parasites. For anisakid abundance, the significance of the host sex were positive for both females and males, although, with greater estimates for males (Table 4). Despite the small sample represented by the population of males, the model selection based on AICc and AICc weight evidenced that the best model included the host sex as an explanatory variable for abundance of parasites (Table 3). These differences between females and males, in the susceptibility to acquire more or less parasites could be the result of seasonal and spatial differences in sex ratio, maturity stages and feeding intensities exhibited by *T. lepturus* (MARTINS; HAIMOVICI, 2000). Such differences were also verified by Silva et al. (2000), who observed that males and females were more prevalently parasitized by, respectively, *Callitetrarhynchus gracilis* (Rudolphi, 1819) and *S. pleuronectis*; and females were more abundantly parasitized by *Octoplectanocotyla trichiuri* Yamaguti, 1963.

In the present study we observed a positive influence from abundances of *Polymorphus* sp. and *Octoplectanocotyla travassosi* Carvalho and Luque, 2012 on the abundance of *L. microstomum*; and a negative influence on Anisakidae (Table 4). *Polymorphus* sp. and *O. travassosi* were diagnosed with higher abundance and intensity of infection in females (without statistical significance; results not shown). The female host sex represented one of the positive predictors for the abundance of *L. microstomum* and a negative descriptor for anisakids, which would probably lead to misinterpretation.

The prevalence and abundance of Trypanorhyncha cysts were positively predicted by the weight and length of hosts, respectively. However, the GLM showed that males were the best positive predictor of the abundance of Trypanorhyncha cysts (Table 4). But, considering the negative relationship between the abundance of Trypanorhyncha cysts and anisakids (Table 4), it is possible that these cysts are also influenced by the abundance of anisakid larvae. Still, the capsalid and *S. pleuronectis* were negative and positive descriptors, respectively, of the abundance of *L. microstomum* and anisakids (Table 4). Nevertheless, the capsalid was recovered from a single host of smaller classes of length (89-93 cm) and weight (404-460 g). In turn, *S. pleuronectis* showed a higher prevalence in hosts of smaller classes of length and weight (prevalence of 32 and 34%, respectively), but greater abundance in hosts of smaller length classes, once it was observed in hosts of intermediate weight (534-580 g). These host traits were important predictors of the abundance of *L. microstomum* and Anisakidae, suggesting an interface among these five taxa (Trypanorhyncha cysts, capsalid, *S. pleuronectis*, anisakid and *L. microstomum*), but with Trypanorhyncha cysts and *S. pleuronectis* occupying different niches compared to *L. microstomum* and Anisakidae.

Traits of hosts seem to have a strong influence on abundance of parasites of *T. lepturus*. But access the influences that parasites can exert in host is not a simple task. Especially because induced changes can be associated with host mortality, which is difficult to measure in wild. Thus, include some measure of survivorship could be useful to provide adequate interpretation to manipulation of host parasite-induced (FULLER; BLAUSTEIN, 1996). Other aspect that could be explored is the cannibalism experienced by *T. lepturus* (BITTAR; DI BENEDITTO, 2009; MARTINS et al., 2005) that probably influences the parasitic community and consequently the degree with those parasites manipulates its hosts. So, investigate whether some

parasites may limit cannibalism would be another very interesting topic (BOLKER, et al., 2008).

Conclusion

The parasite community of *T. lepturus* from São Paulo State, Brazil, was a partly structured assemblage. The most prevalent parasites or those with a nonrandom distribution across host size, weight and sex-classes exploit resources differently, which suggest a low niche overlap. These results allow postulating the way some parasites, mainly *L. microstomum* and larvae of Anisakidae, infect their hosts and the consequences of these interactions for this host-parasite system.

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