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Original paper

Similarity of the parasite communities of codlings *Urophycis brasiliensis* and *U. mystacea* (Gadiformes: Phycidae) from the Brazilian coastal zone

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ABSTRACT. A total of 182 specimens of codling, 107 *Urophycis brasiliensis* (Kaup, 1858), and 75 *U. mystacea* Miranda Ribeiro, 1903 from the coastal zone of the states of Rio de Janeiro (RJ) and Santa Catarina (SC), Brazil was examined to study the composition and structure of their parasite communities. A total of 1,684 individual parasites were collected: 506 in *U. brasiliensis* and 444 in *U. mystacea* from RJ; 328 in *U. brasiliensis* and 406 in *U. mystacea* from SC. There was a total of 21 species in the parasite communities of codlings from Rio de Janeiro (RJ) and Santa Catarina (SC) localities. *Urophycis brasiliensis* presented a total of 18 species of parasites, being 16 and 12 species in RJ and SC, respectively. The parasite infracommunities of *U. brasiliensis* and *U. mystacea* from Rio de Janeiro and Santa Catarina were significant different in the mean total abundance and Brillouin diversity index values. *Urophycis brasiliensis* and *U. mystacea* from Santa Catarina present differences in the mean parasite richness, mean total abundance, values of the Brillouin diversity index and the values of Bray-Curtis and Jaccard indexes. However, it was observed higher similarity between the parasite infracommunities of *U. brasiliensis* and *U. mystacea* from Santa Catarina. Samples studied of *U. mystacea* showed significant differences suggested the presence of different stocks of this species, however, this possibility needs to be confirmed with studies using multivariate analysis of additional samples along the geographical distribution area of this species. These results emphasized the necessity for understanding the influence of ecological factors on the composition and structure of parasite communities of the marine fish from Brazil.

Keywords: community ecology, metazoan parasites, *Urophycis*, Rio de Janeiro, Santa Catarina, Brazil

Introduction

The codlings, *Urophycis brasiliensis* (Kaup, 1858) and *Urophycis mystacea* Miranda Ribeiro, 1903, constitutes a valuable resource for the artisanal fisheries of Brazil, Argentina, and Uruguay [1–4]. Brazilian codling *U. brasiliensis* is one of the main commercial coastal species registering industrial and artisanal landings that exceed two thousand tons per year for these countries [5] and is a fishery resource probably overexploited [4].

Studies of marine fish parasite communities from neotropics, focused on the structure, composition and ecological factors have increased in recent decades [6–10]. Nevertheless, little is known about the influence of local or regional factors and the geographic distribution the parasite diversity of congeneric hosts.

Kennedy and Bush [11], in a classic paper, stated that a high similarity between the parasite communities of congeneric host species presents also specific groups of congeneric parasites. In South America, studies using different families from congeneric marine fishes showed varying degrees of similarity between their parasite communities [12–22], however, most of these studies were just descriptive without detailed statistical analysis to detect possible patterns of similarity and without testing qualitative and quantitative similarity in a parasite infracommunity level.

The codlings, *Urophycis brasiliensis* and *U. mystacea* are endemic to the South American

Atlantic [23,24] and present an overlapping and complementary geographic distribution [25,26]. The codling species overlapping distribution could be extended to the components of their parasite communities and its biodiversity as suggested by Alves et al. [18,27]. Pereira et al [22] used the geographic distribution of *U. brasiliensis* as model for discriminated stocks and as indicators of marine ecoregions in coastal areas of the South American Atlantic. In this paper, the composition and structure of parasite community among the congenerics *U. brasiliensis* and *U. mystacea* are studied to detect patterns of similarity between fish samples from two Brazilian states (Rio de Janeiro and Santa Catarina).

Materials and Methods

Collection and processing of fish and parasites

A total of 182 codling specimens were examined: 107 *U. brasiliensis* and 75 *U. mystacea* from the states of Rio de Janeiro, RJ (locality of Cabo Frio 22°52′S, 42°01′W) and Santa Catarina, SC (locality of Florianópolis, 27°35′S, 48°33′W), Brazil, in October 2012. The distance between the two localities is approximately 840 km in straight line. From the studied specimens of *U. brasiliensis*, 67 were captured in RJ and 40 in SC. In *U. mystacea*, 40 specimens were from RJ and 35 from SC. The mean total length (cm) of the specimens of *U. brasiliensis* from RJ was 26.6±2.7 and from SC 34.92±3.1. The mean total length (cm) of the specimens of *U. mystacea* from RJ was 26.0±1.3 and from SC 25.87±2.3.

Fish were identified according to Figueiredo and Menezes [29]. The codlings were kept fresh or frozen in plastic bags at −18°C until examination and identification. Parasites were collected from the body surface, gills, body cavities and viscera after examination under a stereoscopic microscope. Gill washes and intestinal lumen were examined, to collect parasites, using a sieve (154 µm mesh size).

Statistical analysis

Prevalence, mean intensity followed by the range, and mean abundance were calculated for all parasite species of both host species according to Bush et al. [30]. Chi-square analyzes were used to test significant differences in the prevalence for those parasite species with a prevalence greater than 10% and common to the two host species (component species sensu Bush et al. [31]). Student's t-test was used to assess significant differences in abundance in the two codling species [32]. Data were previously transformed by log10 (x+1). The level of statistical significance was $P<0.05$.

The following descriptors were calculated at the parasite infracommunity level: number of parasites per host individual (total abundance), species richness, Brillouin diversity index (log base 10), Evenness index, and Berger-Parker dominance index. Mean total abundance refers to average of the values of total abundance in a set of infracommunities. In addition, two similarity measures, the Jaccard qualitative and the Bray-Curtis quantitative indices were calculated among parasite infracommunities between host species and localities [33]. These indices were calculated with the Primer® software (version 6.1.16) [34]. Student‘s t-test was used to assess significant differences in values of the infracommunity descriptors in the two codling species [32].

Results

One hundred sixty-six fishes were parasitized by one or more helminth species, prevalence of 91% (54 *U. brasiliensis*, 39 *U. mystacea* from RJ; 38 *U. brasiliensis*, 35 *U. mystacea* from SC). A total of 1,684 individual parasites were collected: 506 in *U. brasiliensis* and 444 in *U. mystacea* from RJ; 328 in *U. brasiliensis* and 406 in *U. mystacea* from SC. The mean intensity of parasites was 2.2 (1–36). The distribution of species richness in the parasite infracommunities of the two species of hosts showed that in RJ most of individuals of *U. brasiliensis* were parasitized with only two species 35% (19/54), while in *U. mystacea* most were infected with four species 39% (15/39). Similarly, it was observed in SC, most of *U. brasiliensis* were infected with one species 32% (12/38) while with four in *U. mystacea* 29% (10/35). In SC all *U. mystacea* were parasitized at least with one species.

There was a total of 21 species in the parasite communities of codlings from Rio de Janeiro (RJ) and Santa Catarina (SC) localities. *Urophycis brasiliensis* presented a total of 18 species of parasites, being 16 and 12 species in RJ and SC, respectively. The digeneans *Derogenes varicus* (Müller, 1784) Looss, 1901; *Ectenurus virgula* Linton, 1910 and *Stephanostomum* sp., and larvae of the nematode *Contracaecum* sp. occurred only in *U. brasiliensis* from RJ while the copepod

Table 1. Prevalence (P%), mean intensity (MI) followed by the range and mean abundance (MA) of the metazoan parasites of *Urophycis brasiliensis* and *Urophycis mystacea* collected from the coastal zone of the States of Rio de Janeiro (RJ) and Santa Catarina (SC), Brazil

Host	*Urophycis brasiliensis*						*Urophycis mystacea*					
	RJ			SC			RJ			SC		
	P%	MI (range)	MA	P%	MI (range)	MA	P%	MI (range)	MA	P%	MI (range)	MA
MONOGENEA												
Pseudempleurosoma sp.	13	2.1 (1–4)	0.3	10	2.3 (1–3)	0.2	63	6.8 (1–23)	4.0	94	4.5 (1–9)	4.2
DIGENEA												
Aponurus laguncula	4	4.5 (1–36)	1.7	–	–	–	35	2.5 (1–6)	0.8	40	2.6 (1–6)	0.8
Cainocreadium oscitans	8	2.8 (1–7)	0.2	3	2	0.1	15	4.3 (1–6)	0.6	14	2.2 (1–3)	0.2
Derogenes varicus	1	1	0.01	–	–	–	–	–	–	–	–	–
Ectenurus virgula	3	2 (1–3)	0.05	–	–	–	–	–	–	–	–	–
Lecithocladium cristatum	–	–	–	–	–	–	–	–	–	37	2.6 (1–7)	0.9
Lecithochirium microstomum	6	1.8 (1–3)	0.1	10	1.5 (1–3)	0.5	45	3.3 (1–8)	1.5	23	2.5 (1–8)	0.9
Parahemiurus merus	9	3.8 (1–13)	0.3	–	–	–	5	2.5 (2–3)	0.1	–	–	–
Pseudolepidapedon brasiliensis	27	2.7 (1–6)	0.7	13	2.6 (1–7)	0.3	5	2.5 (2–3)	0.1	3	5	0.1
Stephanostomum sp.	7.5	1.4 (1–3)	0.1	–	–	–	–	–	–	–	–	–
CESTODA												
Nybelinia sp. (plerocercoid)	25	2 (1–6)	0.5	15	1.2 (1–2)	0.2	8	1	0.07	11	1	0.1
Scolex sp.1 (plerocercoid)	–	–	–	–	–	–	13	1.2(1–2)	0.12	–	–	–
NEMATODA												
Capillaria gracilis	–	–	–	20	1.5 (1–2)	0.3	–	–	–	17	1.8 (1–3)	0.3
Contracaecum sp. (larvae)	3	1.5 (1–2)	0.04	–	–	–	–	–	–	–	–	–
Cucullanus cirratus	55	3.2 (1–19)	1.7	70	6.0 (1–24)	4.0	73	3.6 (1–14)	3.5	77	3.8 (1–19)	3.7
Hysterothylacium sp. (larvae)	5	1 (1)	0.04	13	1.2 (1–2)	0.1	8	1	0.07	14	1	0.1
Procamallanus halitrophus	14	3.5 (1–22)	0.1	53	3.5 (1–16)	1.8	18	3.7 (1–13)	3.7	11	1	0.1
Terranova sp. (larvae)	–	–	–	–	–	–	–	–	–	23	1	0.2
ACANTHOCEPHALA												
Bolbosoma turbinella	28	1.9 (1–5)	0.5	35	1.9 (1–4)	0.7	10	1	0.1	11	1	0.1
Corynosoma australe (cystacanth)	–	–	–	10	1.8 (1–3)	0.2	13	1	0.1	–	–	–
Acanthocondria triangularis	3	2 (1–2)	0.04	8	1	0.1	–	–	–	–	–	–

Acanthochondria triangularis Alves, Luque and Paraguassu, 2003 was found only in *U. brasiliensis* in both localities.

Samples of *U. mystacea* presented a total of 16 species of parasites occurring 13 species in RJ and SC. The cestode *Scolex* sp., the digenetic *Parahemiurus merus* (Linton, 1910) Manter, 1940 and the cystacanth *Corynosoma australe* Johnston, 1937 occurred only in RJ, whereas the nematodes *Capillaria gracilis* (Bellingham, 1840), *Terranova* sp. (larvae) and the digenean *Lecithocladium cristatum* (Rudolphi, 1819) Looss, 1907 were found only in SC. The monogenean *Pseudempleurosoma* sp. was the most prevalent and abundant species in *U. mystacea* from SC, while the nematode *Cucullanus cirratus* Müller, 1777 was the most prevalent and abundant in RJ. The digenean *Parahemiurus merus* (Linton, 1910) Manter, 1940 and the nematode *C. gracilis* occurred in both hosts only in RJ and SC, respectively. Both host species presented greatest species richness of digenetics in the component community, eight and six species in *U. brasiliensis* and *U. mystacea*, respectively. Moreover, the nematodes represented the highest species richness (Tab. 1).

The prevalence and abundance of shared parasites in the two localities, are significantly different, except for *C. cirratus* and *Procamallanus halitrophus* Fusco and Overstreet, 1978 (Tab. 2). The monogenean *Pseudempleurosoma* sp. and acanthocephalan *Bolbosoma turbinella* (Diesing, 1851) Porta, 1908 showed values of prevalence and abundance significantly different among the codling species from RJ and SC. The first one presented greater prevalence and abundance in *U. mystacea* and the second one in *U. brasiliensis*. The abundance of the nematode *C. cirratus* in *U. mystacea* was significantly higher than in *U. brasiliensis* still from RJ. Differently, in SC only the prevalence and abundance of the nematode *P. halitrophus* was significantly higher in *U. brasiliensis,* whereas abundance of the digenetic *Lecithochirium microstomum* Chandler, 1935 was significantly higher in *U. mystacea* (Tab. 2).

Comparing the metazoan parasite infracommunities of *U. brasiliensis* and *U. mystacea* from RJ there were significant differences in the mean total abundance and mean Brillouin diversity index. Furthermore, in the two species of codlings from SC there were significant differences in mean parasite richness, mean total abundance, Brillouin diversity index values, and Berger-Parker

a

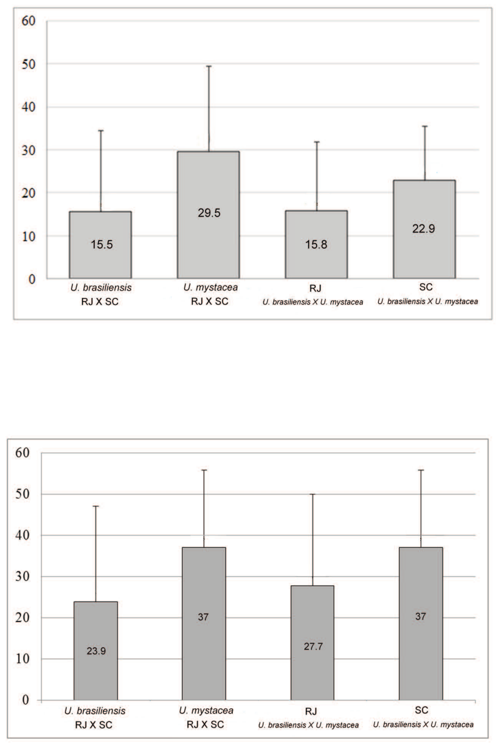

Figure 1. Similarity indexes between the parasitic communities of *Urophycis brasiliensis* and *Urophycis mystacea* from the coastal zone of the states of Rio de Janeiro (RJ) and Santa Catarina (SC), Brazil. (a) Values of Bray-Curtis Quantitative Similarity Index (mean and standard deviation), (b) Values of Jaccard Qualitative Similarity Index (mean and standard deviation)

dominance index (Tab. 3). Additionally, variability among communities of the two fishes in both localities were observed when analysed using the Jaccard qualitative and Bray-Curtis quantitative indices (Figs 1a,1b) (see standard deviation). The infracommunities were more similar between *U. brasiliensis* e *U. mystacea* from SC than from RJ. Moreover, greater similarity was also detected between parasite communities from *U. mystacea* in the two localities (Figs 1a,1b).

Discussion

The composition of the parasite communities at the large spatial and temporal scales proceeds through a series of evolutionary events, which can be determinate, in part, by the characteristics of the habitat or the host [35]. In the present study was reported 18 species parasitizing *U. brasiliensis*, previously, Alves et al. [28] reported 22 parasite species while only six species are common in both studies. However, for *U. mystacea* similar finding

Table 2. Comparison of the values of prevalence (χ^2) and mean abundance (*t*) of metazoan parasites (with prevalence>10%) of *Urophycis brasiliensis* (Ub) and *Urophycis mystacea* (Um) from the coastal zone of the States of Rio de Janeiro and Santa Catarina, Brazil

Parasites species	Rio de Janeiro				Santa Catarina			
	Prevalence		Mean abundance		Prevalence		Mean abundance	
	χ^2		*t*		χ^2		*t*	
Pseudempleurosoma sp.	**25.5***	Um>Ub	**-5.2***	Um>Ub	**53.1***	Um>Ub	**-10.9***	Um>Ub
Aponurus laguncula	0.2	–	-0.2	–	–	–	–	–
Lecithochirium microstomum	–	–	–	–	4.1	Um>Ub	**-2.8***	Um>Ub
Nybelinia sp.	–	–	–	–	0.2	–	0.6	–
Capillaria gracilis	–	–	–	–	0.1	–	0.1	–
Cucullanus cirratus	3.2	–	**-2.1***	Um>Ub	0.9	–	0.7	–
Hysterothylacium sp.	–	–	–	–	0.1	–	1.5	–
Procamallanus halitrophus	1.6	–	1.0	–	**14.2***	Ub>Um	**4.3***	Ub>Um
Bolbosoma turbinella	**5.0***	Ub>Um	**3.2***	Ub>Um	**5.7***	Ub>Um	**2.9***	Ub>Um

was described by Alves et al. [27], 16 parasite species were reported in the same host from the coastal zone of the State of Rio de Janeiro. Although only 3 species were common in both studies. According to Poulin [35], it is expected that in short periods of time the component communities show little variations in their parasite diversity, since colonization of new hosts is a long-term process and exceedingly difficult to be evaluated. Furthermore, macroecological differences in the region along the years are expected and can determine the decrease or displacement of some food items that can function as intermediate hosts for some parasites, explaining in part these differences in the parasite communities in different periods of studies. Indeed, the influence of ecological factors related to the feeding of hosts on the diversity and presence, or absence of parasites have been pointed extensively [36–38].

Urophycis brasiliensis and *U. mystacea* shared many parasite species in both localities, however, the parasite community structure showed different

Table 3. Characteristics of metazoan parasite infracommunities of *Urophycis brasiliensis* and *Urophycis mystacea* from the coastal zone of the States of Rio de Janeiro and Santa Catarina, Brazil. *t* = Student test values for comparison between hosts

Characteristics	Rio de Janeiro			Santa Catarina		
	U. brasiliensis	*U. mystacea*	*t*	*U. brasiliensis*	*U. mystacea*	*t*
Species richness	16	12	–	13	13	–
Total number of specimens	506	520	–	320	406	–
Mean species richness	2.7±1.55	3.1±1.223	-1.668	2.5±1.396	3.9±1.662	**-3.819***
Mean total abundance	7.7±8.26	11.1±7.56	**-2.977***	8.2±6.975	11.6±6.634	**-2.630***
Mean Brillouin index	0.51±0.38	0.63±0.32	**-4.978***	0.45±0.385	0.79±0.351	**-3.845***
Mean Evenness index	0.89±0.12	0.81±0.17	-0.411	0.82±0.146	0.86±0.103	-0.397
Mean Berger–Parker index	0.58±0.27	0.59±0.23	-0.375	0.69±0.257	0.52±0.191	**0.371***

* Significant values ($P < 0.05$)

values of the descriptive parameters (prevalence, intensity and/or abundance). Interestingly, the prevalence and abundance of the only monogenean reported were significantly higher in *U. mystacea* in both regions, and the same pattern was also observed for the acanthocephalan *B. turbinella* in *U. brasiliensis*. Additionally, there were species that occurred only in RJ or SC (*P. merus* and *C. gracilis*, respectively), in contrast, there were species that occurred only in determinated host and specific locality (i.e., *Contracaecum* sp., *Scolex pleuronectis* Müller, 1788; *D. varicus*, *L. cristatum*, among others). Variations in the parasitological parameters are expected due to the ecological and physiological variables of the hosts [35]. Although *U. brasiliensis* and *U. mystacea* present complementary distribution, they inhabit different depths [39–41]. Adults from *U. brasiliensis* are found in depths from 50 to 100 meters and juveniles from 30 meters [41]. The species *U. mystacea* occurs from 180 to 600 meters [24,39,42]. Moreover, on the shelf coastal waters *U. brasiliensis* feeds on shrimps, crabs and to a lesser degree on fish while the congeneric species *U. mystacea* feeds of benthic crabs, shrimps, cephalopods, and small pelagic-benthonic fishes [43]. Thus, related species can differ the food resources and habitat avoiding competition [35] and present different structure parasite community and component species. This pattern was also observed in congeneric species of other vertebrates hosts as rodents and lizards [44,45].

Furthermore, congeneric host species could share their habitat and have a similar parasite fauna. Muñoz and Rebolledo [46] reported that the congeneric and sympatric fishes *Notothenia rossii* Richardson, 1844 (marbled rockcod) and *Notothenia coriiceps* Richardson, 1844 (black rockcod) collected from Antarctic, presented high similar parasite communities, suggesting that they are using food resources in an analogous way. In Brazil, a similar pattern was observed for the marine fishes *Caranx hippos* (Linnaeus, 1766) (crevalle jack) and *Caranx latus* Agassiz, 1831 (horse-eye jack) [15] and *Pseudopercis numida* Miranda Ribeiro, 1903 (namorado sandperch) and *Pseudopercis semifasciata* (Cuvier, 1829) (Argentinian sandperch) [18]. Alves et al. [16] stated that the similarity of the structure and composition of the parasite communities of the grey and queen tiggerfish *Balistes capriscus* Gmelin, 1789 and *Balistes vetula* Linnaeus, 1758 could be originated by the overlapping of the diet spectrum and ecological niche.

The parasite communities of *U. brasiliensis* and *U. mystacea* showed significant differences and a low degree of similarity in Rio de Janeiro. However, in the samples from Santa Catarina showed a greater similarity, probably it was influenced by the similarities of the parasite richness values in this location. The values of the qualitative similarity indices (based on presence-absence analysis) that evaluate the component communities tend to be higher than the values obtained with the quantitative similarity indices that evaluate the infracommunities, therefore, the size of the infrapopulations [6]. The aggregation characteristics of parasitism could contribute to the heterogeneity and to the low values found in these analyses, however, patterns of similarity can be observed between the parasite communities of distinct groups of hosts, especially when confronted with different characteristics of their biology [6,47].

In addition, the greater parasite means richness and diversity values of fish from the coast of the of SC could be explained, in part, by the encounter of two important marine currents in this region (Current of Malvinas and Current of Brazil). It originates a key area for feeding and reproducing organisms known as the Subtropical Convergence Zone [48]. This oceanographic transition zone may represent the northern limit of species characteristic of colder regions or the southern limit for more tropical species, besides receiving migratory birds and aquatic mammals from both hemispheres that can function as definitive hosts for several species of endoparasites of marine fish. Furthermore, differences between infracommunities and component communities from a specific host in different geographical patterns can be consequence of variability in parasite availability in the different regions and variation among species in terms of host specificity and life-cycles strategies as observed by Timi et al. [6] for another teleost fish, *Pinguipes brasilianus* Cuvier, 1829 (Brazilian sandperch), in the southwestern Atlantic.

The biodiversity and structure of parasite communities of the codlings have allowed their use as model for studies about the discrimination of fish stocks and ecoregions. Pereira et al. [22] through a parasitological study using samples of *U. brasiliensis* from Brazil and Argentina determined the presence of 3 fish stocks belonging to different biogeographic ecoregions (Southeastern Atlantic = Rio de Janeiro+Santa Catarina, Brazil; Rio Grande, Rio Grande do Sul, Brazil and Mar del Plata Buenos Aires, Argentina), resulting in relevant information for the management of this fishery resource. Biolé et al. [5] confirmed this result identifying different stocks from Brazil and Argentina using otolith shape and fingerprints. In the present paper, samples studied of *U. mystacea* from the southeastern (RJ) and southern (SC) regions of Brazil showed significant differences suggesting the presence of different stocks of this species, however, this possibility needs to be confirmed with studies using multivariate analysis of additional samples within the geographical distribution area of this species.

The low values obtained by the similarity indices when comparing the parasite communities of the two godling species from the studied localities, emphasize the need to understand the influence of ecological factors on the composition and structure of parasite communities as proposed by Holmes [49]. As marine fish studied species belongs to the same genus and from the same location, the relevance of ecological aspects in the characterization of parasite communities is evident. Therefore, this knowledge may become an important subsidy for the management of several species of marine fishes on the Brazilian coast, especially in species such as codlings, mainly *U. mystacea*, that, although of great economic importance, have been little studied for other biological aspects.

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