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Seasonal variability of the composition and structure of parasite communities of red porgy, *Pagrus pagrus* (Perciformes: Sparidae) off Brazil

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Summary

A study of seasonal variation of metazoan parasite community of *Pagrus pagrus* was conducted between January and December 2012. Two hundred forty specimens of *Pagrus pagrus* were collected in four seasons (autumn and winter in dry season and spring and summer in rainy season) from off the state of Rio de Janeiro, Brazil. Twenty one species of metazoan parasites were found, with larvae of *Hysterothylacium* sp. being the dominant species. The highest values of prevalence and abundance was during the rainy season with peak prevalence of monogeneans and nematodes, period of action of the South Atlantic Central Waters (SACW) and reproductive activity of the host, suggesting that the seasonal variation in the parasites community was influenced for these phenomena.

Keywords: *Pagrus pagrus*; seasonal variation; metazoan parasites

Introduction

Parasitism plays an important role in biology of fish because parasites influence host survival and reproduction; they can also alter fish behaviour and migration patterns, and can even regulate fish populations and affect fish community structure (Gordon & Rau, 1982; Poulin & Fitzgerald, 1987; Garnick & Margolis, 1990; Barber & Poulin, 2002).

A large number of studies have focused on the structure of communities of parasites of marine fish. However, many of them did not consider spatial and temporal variations in community structure, and thus the detection of relevant local or short-term processes (Poulin & Valtonen, 2002). Studies related with the population and community ecology of fish parasites are carry out in order to determine their natural modifications, including both biotic and abiotic factors of the host-parasite system that affect its dynamics (Díaz & George-Nascimento, 2002).

Processes such as variations in temperature and other abiotic factors, the abundance of intermediate hosts, changes in abundance, reproductive behaviour and diet of definitive hosts and factors related to host immunity have been suggested to influence the seasonal variation in communities of parasites of marine fish in tropical regions (Carvalho & Luque, 2011; Soares *et al.*, 2014).

Thus, seasonal studies are necessary to elucidate additional aspects of the structures of the parasite community in *P. pagrus*.

Pagrus pagrus popularly known as red porgy is a demersal fish, which feeds on a wide variety of benthic and demersal fish, and invertebrates. It is a fish of significant commercial value (Ávila & Haimovici, 2004) and is widely distributed in the Eastern Atlantic since the British Isles south to coastal zone of Angola, also occurring in the Mediterranean and the Adriatic Sea. In the Western Atlantic is distributed from the coast of New York, USA to southern Argentina (Manooch & Hassler, 1978; Menezes & Figueiredo, 1980). The main objective of this work was to detect possible patterns of seasonal variability in the composition and structure of parasite communities of *Pagrus pagrus*, in the coast of Rio de Janeiro, RJ, Brazil.

Material and Methods

We examined 240 specimens of *Pagrus pagrus* collected from the coast of Municipality of Cabo Frio, State of Rio de Janeiro (22°52'43"S, 42°1'12" W), Brazil between January and December 2012. The sample fish were divided into 4 groups of 60 individuals for every season, i.e. autumn and winter (dry season) and spring and summer (rainy season). Host specimens were identified according to

Table 1. Prevalence, range of variation of intensity, mean intensity, mean abundance and site of infection of metazoan parasites of *Pagrus pagrus* (n = 240) from the coastal zone of the state of Rio de Janeiro, Brazil

Parasite	Prevalence (%)	Intensity	Mean Intensity	Mean Abundance	Site of infection
DIGENEA					
<i>Lecithochirium</i> sp.	5	1 – 11	2	0.13±0.83	Stomach
<i>Parahemiurus merus</i>	8	1 – 12	3	0.23 ±1.30	Intestine
MONOGENEA					
<i>Anoplodiscus longivaginus</i>	15	1 – 6	2	0.27 ±0.80	Gills
<i>Echinopelma brasiliensis</i>	25	1 – 4	1	0.33 ± 0.66	Gills
<i>Encotyllabe spari</i>	65	1 – 41	7	4.68 ± 6.71	Pharyngeal plates
<i>Lamellodiscus baeri</i>	13	1 – 30	4	0.45 ± 2.27	Gills
<i>Polyabroides multispinosus</i>	5	1 – 3	1	0.06 ± 0.29	Gills
<i>Pseudempleurosoma</i> sp.	0.2	1 – 2	1	0.05 ± 0.31	Esophagus
ACANTHOCEPHALA					
<i>Corynosoma australe</i>	2.5	1 – 9	5	0.11 ± 0.84	Mesenteries
NEMATODA					
<i>Anisakis</i> sp. (larval)	23	1 – 65	10	2.38 ± 7.37	Mesenteries and liver
<i>Contracaecum</i> sp.(larval)	4	1 – 9	3	0.12 ± 0.74	Mesenteries and liver
<i>Hysterothylacium</i> sp. (larval)	92	1 – 156	25	22.9 ± 26.1	Mesenteries and liver
<i>Raphidascaris</i> sp.(larval)	13	1 – 59	10	1.28 ± 5.59	Mesenteries and liver
<i>Terranova</i> sp.(larval)	3	1 – 9	4	0.13 ± 0.84	Mesenteries and liver
<i>Cucullanus</i> sp.	2	1 – 2	2	0.03 ± 0.20	Intestine
COPEPODA					
<i>Clavellotis pagri</i>	32	1 – 10	2	0.74 ± 1.55	Gill rakers
<i>Ergasilus</i> sp.	0.3	1	1	0.03 ± 0.17	Gills
<i>Lernanthropus caudatus</i>	9	1 – 4	2	0.16 ± 0.61	Gills
ISOPODA					
Cymothoid larval	25	1 – 672	48	12.3 ± 56.7	Gills
Cymothoidae gen. n.	0.3	1	1	0.03 ± 0.18	Gills

Menezes and Figueiredo (1980); their total body length was 18–42 cm (mean 32.2 ± 5 cm). The collection and processing of the parasites was made according to Eiras *et al.* (2006). The identification of the parasites follows Tavares and Luque (2006) for anisakid larvae, Cohen *et al.* (2013) for Monogenea, Kohn *et al.* (2007) for Digenea, and Santos *et al.* (2008) for Acanthocephala and Luque *et al.* (2013). The statistics analysis included only parasite species with prevalence higher than 10 % (Bush *et al.*, 1990). In all comparisons, data were considered significantly different when a bilateral obtained probability $p < 0.05$. Analysis of variance (ANOVA) of transformed data with $\log(x + 1)$ was used to compare parasite abundance. Chi-square test analyzes were used to test for significant differences in the prevalence values (Zar, 1996). Non-metric multidimensional scaling (NMDS) based on the Bray-Curtis simi-

larity index was used to obtain an ordination of the infracommunity metazoan parasites according to their relative similarities in parasite abundances. This analysis was performed using 100 random departures with two and three-dimensional configurations in order to find the optimum ranking. All the methods yielded similar results, but three-dimensional ranking based on the $\log(x + 1)$ transformation was ultimately chosen because it provided the best quality ranking (assessed using the stress value and inspection of Shepard plots). One-way analysis of similarity (ANOSIM) was used to determine the significance of possible grouping patterns in the NMDS ranking (Clarke, 1993). The differences in infracommunity composition were tested through one-way permutational multivariate analysis of variance (PERMANOVA) a permutation of residuals with a reduced model was used as method of permutation.

Table 2. Comparison of prevalence (P%) and mean abundance (Ma) of metazoan parasites (prevalence > 10%) of *Pagrus pagrus* of the coastal zone of Rio de Janeiro, Brazil in different seasons

Species	Summer			Autumn			Spring			Winter		Prevalence	Abundance
	P(%)	Ma	P(%)	P(%)	Ma	P(%)	P(%)	Ma	P(%)	Ma	P(%)	x ²	ANOVA F
<i>Anoplodiscus longivaginatus</i>	12	0.18 ± 0.65	22	0.30 ± 0.65	15	0.20 ± 0.66	17	0.38 ± 1.14	8.29*	0.15			
<i>Echinopelma brasiliensis</i>	28	0.33 ± 0.63	28	0.28 ± 0.49	33	0.47 ± 0.89	20	0.25 ± 0.57	3.86	4.05*	Sum-Aut		
<i>Encotyllabe spari</i>	15	0.15 ± 0.44	70	4.27 ± 5.53	100	8.95 ± 7.92	78	5.25 ± 7.03	17.85*	0.08			
<i>Lamellodiscus baeri</i>	15	0.30 ± 1	15	0.20 ± 0.68	22	1.13 ± 4.28	8	0.17 ± 0.72	37.3*	0.23			
<i>Anisakis</i> sp.	52	3.9 ± 6.8	25	4.17 ± 12.10	17	0.92 ± 3.5	5	0.32 ± 1.47	14.71*	1.13			
<i>Hysterothylacium</i> sp.	93	18.23 ± 18.1	90	26.02 ± 32.4	93	24.52 ± 27.45	93	22.27 ± 24.32	25.36*	0.70			
<i>Raphidascaris</i> sp.	32	4 ± 10.16	12	0.25 ± 1	17	0.58 ± 2.34	2	0.05 ± 0.39	176.0*	0.49			
<i>Clavellotis pagri</i>	43	0.87 ± 1.44	25	0.78 ± 2	37	0.75 ± 1.53	32	1.17 ± 4.72	3.72	0.07			
Cymothoid larval	7	1.23 ± 8	52	32.88 ± 99.8	13	0.80 ± 3	37	13.47 ± 47.45	2329.6*	0.14			

* significant values

Table 3. Quantitative features in the infracommunity metazoan parasites of *Pagrus pagrus* coastal area of the state of Rio de Janeiro, Brazil. F = values from ANOVA for comparison between the hosts

Features /species	Summer	Autumn	Winter	Spring	ANOVA F
Richness of species	19	19	18	18	
Total number of specimens	1.839	4.188	2.664	2.395	
Average parasite richness	3.4 ± 1.4	3.7 ± 1.6	3.2 ± 1.4	3.8 ± 1.4	0.514
Total average abundance	0.15 ± 0.44	4.27 ± 5.53	5.25 ± 7.03	8.9 ± 7.9	0.324
Brillouin index (average value)	0.61 ± 0.26	0.61 ± 0.36	0.41 ± 0.36	0.72 ± 0.29	0.059
Dominant species	<i>Hysterothylacium</i> sp.	<i>Hysterothylacium</i> sp.	<i>Hysterothylacium</i> sp.	<i>Hysterothylacium</i> sp.	
Berger-Parker Index	0.67 ± 0.16	0.70 ± 0.20	0.76 ± 0.18	0.63 ± 0.17	4.85* Sum-Aut

* significant values

A sequential sum of squares (Type I SS) was applied because host size was introduced as a covariable (ANCOVA model) due to the known effect of fish size-age on parasite burdens. The structures of parasite infracommunities between the samples per seasons (1 × 4 factorial design, with seasonal as the random factor) by testing for the main effects after 9,999 permutations. The differences in

infracommunity composition between were tested using the same samples in a similar way for dry season and rainy season using a 1 × 2 factorial design with tropical climate as the random factor. The same model was tested for differences in dispersion using the PERMDISP routine (Anderson *et al.*, 2008). Dispersion distances to centroids were measured and each term in the analysis was

Fig. 1. Non-metric multidimensional scaling (NMDS) graph on the axes of a two-dimensional solution of tri-dimensional 240 infracommunity helminth based on Bray-Curtis similarities of transformed data log (x + 1) abundance of parasitic (stress = 0.15). Vectors are Spearman correlations of helminth species abundances with NMDS axes. (The circle represents a correlation of 1). Symbols should be interpreted as follows: + summer; Δ Autumn; * winter; ○ spring

tested using 9,999 permutations, with significant terms investigated using a *posteriori* pairwise comparisons with the PERMANOVA t-statistic (Anderson *et al.*, 2008). Statistical analyses were carried out using the PRIMER® v.6 and PERMANOVA + for PRIMER software (Clarke & Gorley, 2006; Anderson *et al.*, 2008).

Results

All specimens of *Pagrus pagrus* examined were infected with at least one parasite species. A total of 11,117 metazoan parasites (helminths and crustaceans) of 21 species were collected (2 adult digeneans, 6 monogeneans, 1 larval acanthocephalan, 6 nematodes – 1 adult and 5 larvae, 3 copepods and 2 isopods – see Table 1). The most prevalent and abundant were anisakid larvae that represented as many as 58 % of all parasites. Out of these, larvae of *Hysterothylacium* sp. were represented by 5.496 specimens (85 %). Anisakid larvae were present in all samples with peak prevalence of *Anisakis* sp. and *Raphidascaris* sp. in summer. *Hysterothylacium* sp. maintained high prevalence in all seasons. Monogeneans had their maximum prevalence and abundance in autumn and spring. Significant difference was found only for the occurrence of *Echinopelma brasiliensis* between the summer and

autumn (ANOVA $F = 4.05$; $P < 0.05$), whereas no seasonal changes were found in the abundance of remaining species (Table 2). Values of mean parasite richness, mean abundance and Brillouin index did not differ between seasons and the Berger-Parker index showed significant difference between summer and autumn (ANOVA $F = 4.85$; $P < 0.05$) (Table 3).

Figure 1 displays the The NMDS ranking of 240 helminth infracommunities that was based on abundance data that had previously been $[\log(x + 1)]$ transformed. The results show a separation observed among spring and summer samples. This pattern was statistically significant (1-way ANOSIM, $P < 0.01$). Species correlation with the NMDS axes (Fig. 1) indicated that the abundance of nematode larvae of *Anisakis* sp. and *Raphidascaris* sp. tended to be positively associated with the summer, whereas monogeneans *Encotyllabe spari* and *Lamellodiscus baeri* with autumn. Similar results were found for dry and rainy seasons (Fig. 2).

The results from the PERMANOVA analysis showed that there was no interaction between host length with the seasons (Table 4). However, the seasonal factor levels differed between seasons. PERMDISP was significant comparing the results confirmed seasonal differences between summer/spring, autumn/spring and winter/spring (Table 4). Results were similar for rainy season and

Fig. 2. Non-metric multidimensional scaling (NMDS) chart on the two-dimensional axes of a three-dimensional solution of 240 infracommunity helminth based on Bray-Curtis similarity of transformed data $\log(x + 1)$ of parasite abundance (stress = 0.15). Vectors are Spearman correlations of helminth species abundances with NMDS axes. (The circle represents a correlation of 1). Symbols should be interpreted as follows: ▼ dry season; △ rainy season

Table 4. Sources of variation in the abundance of seven species of helminths analyzed by permutational multivariate analysis of variance (PERMANOVA) based on Bray-Curtis similarities with transformed abundance data $\log(x+1)$. Permutation test for homogeneity of multivariate dispersion (PERMDISP) was applied to test differences in dispersion between groups formed by the factors in which the values were significant for PERMANOVA

	PERMANOVA		PERMDISP	
	Pseudo-F	P	Pseudo-F	P _(Disp)
Seasons	2.8316	0.0183*	4.4127	0.0268*
Length	0.65379	0.7825		
Seasons x Length	1.2004	0.2498		
	PERMANOVA paired		PERMDISP paired	
	P		P	
Summer - Autumn	0.0001		0.575	
Summer - Winter	0.0001		0.706	
Summer - Spring	0.0001		2.43E-2*	
Autumn - Winter	0.1823		0.3453	
Autumn - Spring	0.0001		1.8E-3*	
Winter - Spring	0.0001		5.4E-2*	

* significant values

dry season without interaction with host length and significant between rainy season (spring and summer) and dry season (autumn and winter) (Table 4).

Discussion

One of the most important aspects of tropical climate is that the annual seasonality is characterized more by water concentration than thermal variation. Most of the area of Brazil is located in the inter-tropical zone. Throughout immense area of the Brazilian territory, there is a clear alternation between dry and rainy season. The austral summer occurs between October and March, a period of more abundant rainfall and higher temperatures (Sant'anna, Neto 2005).

The present study detected seasonal patterns in the occurrence of two species of metazoan parasites of *Pagrus pagrus* with the highest values of prevalence, intensity and abundance of infection. Moreover, there were significant differences in the prevalence and abundance of species collected in two or more seasons. The peaks in parasite prevalence and abundance were mainly in the summer sample for endoparasites and in spring for ectoparasites (rainy season). At the infracommunity level, larvae of anisakid nematodes were dominant in all seasons.

The host length was not determinant in the population parameters of parasites but temporal changes in diet and the biology of the hosts recorded during upwelling and reproduction might influence the degree of infection/infestation of the host, as indicated in the analysis. Total parasite abundance was positively associated with season analysis. In summer, the host population undergoes greater foraging activity in order to store energy for the reproductive

period early winter and late summer.

The period of greatest reproductive intensity of *P. pagrus* off the coast of Brazil is between August and December, with spawning season that extends from November to January (Costa *et al.*, 1997). This coincidence between increased nutrient availability and the reproductive period is a strategy used by marine teleosts to ensure that the larvae have access to a greater concentration of food, thereby preventing their spreading out over a wider area and benefitting their survival (Bakun & Parrish, 1990). The greater foraging activity by *P. pagrus* in summer was reflected in the quantitative and qualitative characteristics of populations of metazoan endoparasites. With the exception of digenean species, a great population aggregation that occurs as a result of reproduction may have led to the greater prevalence and abundance of copepods, represented by *Clavellotis pagri*, throughout the collection period, with peaks during the reproductive period of the fish.

Among the monogeneans, peak prevalence and abundance occurred in autumn and spring, following the end of the peak breeding period of the fish. A number of authors have reported an association between reproduction and an increase in the prevalence and abundance of species of parasites and have attributed this fact to the physiological stress of the host during the breeding period, as a higher investment in reproduction may decrease the energy allocated to the immune system and thereby facilitate parasite infections (Sheldon & Verhulst, 1996; White *et al.*, 1996; Lizama *et al.*, 2006).

Anisakid larvae were found in all samples of the year. The feeding plasticity of *P. pagrus* and its intermediate position in the marine food chain indicate its importance as an intermediate or paratenic host for helminth parasites. Larval stages of nematodes were

found using *P. pagrus* to reach the definitive hosts (Tavares & Luque, 2006). The intermediate hosts used by anisakid are mainly represented by crustaceans, mollusks and fish, which are the predominant items in the diet of *P. pagrus* (Anderson, 2000). Thus, temporal variations in the availability of food items may have repercussions on the parasite fauna of *P. pagrus*, whereas the abundance and prevalence of parasites with complex life cycles depends directly on the free-living fauna (Campbell *et al.*, 1980; Campbell, 1983).

Similar results about seasonality was reported by Carvalho and Luque (2011), composition and structure of parasite communities of *Trichiurus lepturus* as consequence of environmental changes and upwelling, as well as behavioral and physiological changes in host (increase in feeding and reproduction) led to immediate changes.

In rainy season (spring, summer), concentrates the upwelling phenomena, breeding and spawning of *P. pagrus* possible responsible for differences at parasite community in these periods. Suggesting that the seasonal variation in the parasites community was influenced for these phenomena.

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