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Macrofauna inhabiting the sponge *Paraleucilla magna* (Porifera: Calcarea) in Rio de Janeiro, Brazil

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Sponges (phylum Porifera) are important components of the benthic marine fauna known for their interactions with vertebrates and a large sort of invertebrates seeking for food, shelter or substrate for attachment. Studies on this subject, however, were restricted only to the macrofauna inhabiting sponges of the class Demospongiae. In the present work, we describe the macrofauna associated with a calcareous sponge in Brazil, Paraleucilla magna. *Individuals of this allegedly non-native species were monthly collected during one year in Rio de Janeiro (Brazil). Fifty taxa representing 10 animal phyla were found associated with* P. magna. *The most frequent and abundant taxa were Crustacea, Mollusca, Polychaeta and Bryozoa, while echinoderms, cnidarians, ascidians, nemerteans, platyhelminthes and sponges were less frequent or even rare and less abundant. Juveniles of several taxa and pregnant females of Crustacea were found associated with* P. magna, *but these associations were not exclusive. The macrofauna associated with* P. magna *did not present a clear seasonality, although it was possible to observe a change in the community composition alongside the year. The volume of the sponges was significantly related to the diversity index (H′) and number of taxa, but not with evenness (J′) and number of individuals. Our results show that* P. magna *is used as a substrate for attachment and/or shelter by its associates and that most of these associations are just opportunistic. The data presented here reiterate a previous proposal that sponges are important biodiversity reservoirs and that they should be seriously considered in conservation programmes.*

Keywords: macrofauna, sponges, *Paraleucilla magna*, Rio de Janeiro, Brazil

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INTRODUCTION

Sponges (phylum Porifera) have long been considered ‘living hotels’ due to the great diversity and abundance of other taxonomic groups that are often found in association with them (Pearse, 1950; Klitgaard, 1995; Ribeiro *et al.*, 2003). These associations represent a wide range of ecological interactions, facultative or obligatory, that range from mutualism to parasitism; however, the exact nature of many associations remains unclear (Wulff, 2006). Because sponges have bodies composed of an intricate network of canals, associated organisms may find substrate and shelter inside them (Çinar *et al.*, 2002; Huang *et al.*, 2008). As sponges are important components of benthic communities and interact with a wide range of organisms (Wulff, 2006; Becerro, 2008), they are considered to be important reservoirs of marine biodiversity (Cerrano *et al.*, 2006).

Previous studies of sponge-associated fauna have been carried out in the North Atlantic Ocean (Frith, 1976; Biernbaum, 1981; Peattie & Hoare, 1981; Klitgaard, 1995; Huang *et al.*, 2008; Fiore & Jutte, 2010), the Caribbean (Pearse, 1950; Villamizar & Laughlin, 1991), the Mediterranean (Rützler, 1976; Koukouras *et al.*, 1985, 1992, 1996; Ilan *et al.*, 1994; Çinar *et al.*, 2002), the Pacific Ocean (Long, 1968; Magnino *et al.*, 1999; Beaulieu, 2001; Skilleter *et al.*, 2005; Cerrano *et al.*, 2006) and the Indian Ocean (Abdo, 2007). Only three studies have been performed in the South Atlantic Ocean: one in Argentina (Cuartas & Excoffon, 1993) and two in Brazil (Duarte & Nalesso, 1996; Ribeiro *et al.*, 2003). Other studies along the Brazilian coast have revealed associations between sponges and particular groups of organisms: gammarids and caprellids (Serejo, 1998), copepods (Bispo *et al.*, 2006) and polychaetes (Neves & Omena, 2003). With the exception of two studies that focus on hexactinellid sponges (Beaulieu, 2001; Fiore & Jutte, 2010), all studies of sponge-associated fauna focus on the class Demospongiae. Only one study, conducted in Hampshire, England, has investigated the associated fauna of a calcareous sponge. This study, however, found no fauna associated with either *Sycon ciliatum* (Fabricius, 1780) or *Grantia compressa* (Fabricius, 1780) and did not describe any organisms found with *Leucosolenia botryoides* (Ellis & Solander, 1786) (Frith, 1976).

Paraleucilla magna Klautau *et al.*, 2004 is a calcareous sponge found along the Brazilian coast (adjacent to the Rio de Janeiro, São Paulo and Santa Catarina States) and in the Mediterranean (along the southern coast of Italy and around Malta). In both regions, it is considered to be a non-native species, although its origin is still unknown (Klautau *et al.*, 2004; Longo *et al.*, 2007; Zammit *et al.*, 2009; Gravili *et al.*, 2010). It lives attached to hard substrates in photophylous or sciaphylous conditions and in pristine or polluted

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waters (Klautau *et al.*, 2004; Longo *et al.*, 2007; Gravili *et al.*, 2010). This species has a leuconoid aquiferous system with a large atrial cavity and many canals that can be easily occupied by other organisms. In the original description of *P. magna*, crustaceans, echinoderms and polychaetes were described as associating with this species (Klautau *et al.*, 2004); however, there has been no subsequent research on its associated fauna. Therefore, to gain knowledge about the associated macrofauna of calcareous sponges, we investigated the composition of macrofauna inhabiting *P. magna* over the course of one year. The objectives of this study were to: (1) describe the species composition of the associated macrofauna of *P. magna*; (2) investigate the influence of sponge volume on these associations; and (3) analyse the influence of seasonality on these associations.

MATERIALS AND METHODS

Sampling

Five specimens of *P. magna* (Figure 1B) were collected monthly throughout 2005 (except in February, when only four individuals were collected; and in April, when no collection occurred), totalling 54 specimens. All specimens were collected at Vermelha Beach (22°57′18″S–43°09′42″W), in Rio de Janeiro, Brazil (Figure 1A: Lanna *et al.*, 2007). Specimens were collected by snorkelling at 0–4 m depth and were removed from the substrate with a knife. While underwater, each specimen was bagged individually (to avoid the escape of associated organisms) and then fixed and preserved in 93% ethanol. At the laboratory, the volume of each sponge was calculated by liquid displacement in a graduated cylinder (see Ribeiro *et al.*, 2003; Lanna *et al.*, 2007). Sponge specimens were then carefully fragmented under a stereomicroscope to remove the macrofauna (>1 mm) that remained inside. Associated organisms of each sponge specimen were separated by morphotype within higher taxa and then identified to the lowest possible taxonomic level with the help of specialists.

Data analysis

We counted the total number of associated individuals and the total number of taxa to calculate species richness, frequency, abundance, density, diversity (H'), and Pielou's evenness (J') (Ludwig & Reynolds, 1988). To investigate whether the total volume of *P. magna* specimens collected each month (i.e. the sum volume of the five analysed individuals) could predict species richness, abundance, diversity and evenness, we performed a linear regression (Sokal & Rohlf, 1995). The values of species richness, frequency, abundance, density, diversity (H') and Pielou's evenness (J') obtained for each month were used as replicates to test whether these attributes of the associated fauna varied between the dry (April to September) and rainy (October to March) seasons. All data were tested for normality and homoscedasticity prior to performing analyses of variance (ANOVAs). Temporal patterns in the community of associated fauna were assessed by means of a principal component analysis (PCA), in which the dimensionality of 21 species (the number of species that occurred in more than one month) was reduced to only two components (latent variables) representing the primary temporal patterns of dominant species. As most species were rare, and because many zeros were present in the data table (see Table 1), we applied a Hellinger transformation prior to analysis (see Legendre & Gallagher, 2001). PCA scores obtained for each month were used as replicates for the ANOVA to test whether these attributes of the associated fauna varied between the dry and rainy seasons (Jassby & Powell, 1990).

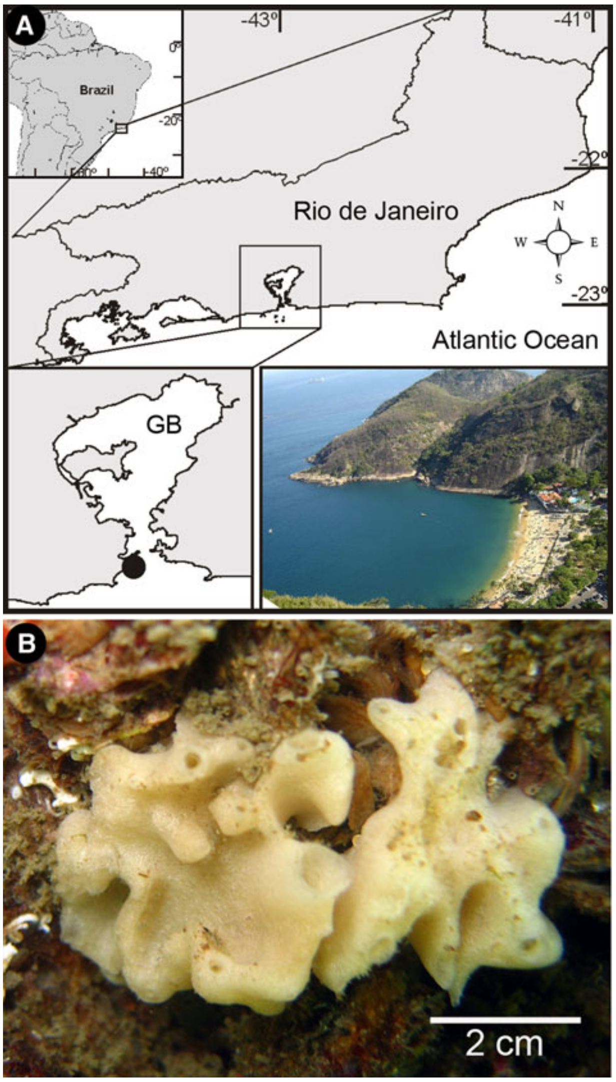

Fig. 1. (A) Map of the study area. Vermelha Beach is located at the entrance of the eutrophic Guanabara Bay (GB) (black dot at inferior left corner). Map source: DIVA-GIS, Vermelha Beach (photograph: F. Azevedo); (B) *in vivo* photograph of *Paraleucilla magna*.

RESULTS

Associated macrofauna

A total of 349 individuals, representing 51 species and 10 phyla, were identified living in association with the 54 analysed specimens of *P. magna* (Table 1). The mean species richness of associated taxa was 11.9 species/month (±4.4: Table 2). Arthropoda (mostly Crustacea) showed the highest species richness (17 species); followed by Annelida, with 11 taxa of polychaetes; and Mollusca, with nine species (Table 1). The

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Table 1. Variation of the number of taxa associated with *Paraleucilla magna*. Colonies of Hydrozoa were not quantified, and their presence is marked with "P". The total number of individuals/colonies for each taxon and month, and the total number of taxa of each phylum (within parentheses), are provided. (Por, Porifera; Cni, Cnidaria; Pla, Plathyhelminthes; Nem, Nematoda; Ann, Annelida; Art, Arthropoda; Mol, Mollusca; Bry, Bryozoa; Ech, Echinodermata; Asc, Ascidiacea). (*) indicates the presence of juveniles.

	Taxa	January	February	March	May	June	July	August	September	October	November	December	Total
Por (1)	*Leucosolenia* sp.	1	0	0	0	0	0	0	0	0	0	0	**1**
Cni (1)	Hydrozoa	0	P	0	0	P	0	P	0	0	P	0	
Pla (1)	*Enchiridium evelinae* (Marcus, 1949)	1	0	0	0	0	0	0	0	0	0	0	**1**
Nem (1)	Unidentified Nememtea	1	0	0	0	0	0	0	0	0	0	0	**1**
Ann (11)	Sabellidae sp.*	1	0	0	0	0	0	0	0	0	0	0	**1**
	Branchiomma luctuosum (Grube, 1869)	1	0	0	0	0	0	0	0	0	0	0	**1**
	Phyllodocidae	1	0	0	0	0	0	0	0	0	0	0	**1**
	Syllidae sp. 1	3	0	0	0	0	0	0	0	0	0	0	**3**
	Syllidae sp. 2	2	0	0	0	0	0	0	0	1	0	0	**3**
	Syllidae sp. 3	1	0	1	1	1	0	0	0	0	0	0	**4**
	Syllidae sp. 4	0	1	0	0	0	0	0	0	0	0	0	**1**
	Syllidae sp. 5	0	0	0	0	1	0	0	0	0	0	0	**1**
	Syllidae sp. 6	0	0	0	0	0	1	0	0	0	0	0	**1**
	Syllidae sp. 7	0	0	0	0	0	0	1	0	0	0	0	**1**
	Naineris setosa (Verrill, 1900)	0	0	0	0	0	0	0	0	0	0	1	**1**
Art (17)	Stenothoidae	1	0	0	2	0	16	6	7	3	21	2	**58**
	Melitidae sp.	0	0	0	0	0	0	2	0	0	1	0	**3**
	Quadrimaera quadrimana (Dana, 1852)	1	0	0	0	0	0	0	1	0	6	0	**8**
	Elasmopus pectenicrus (Bate, 1862)	6	0	1	2	1	2	0	0	0	0	3	**15**
	Dulichiella appendiculata (Say, 1818)	3	0	0	0	0	0	0	0	0	0	0	**3**
	Podoceridae sp.	0	0	0	0	0	0	0	1	0	0	5	**6**
	Corophiidae	0	0	0	0	0	0	0	0	0	1	0	**1**
	Cymadusa filosa (Savigny, 1816)	3	0	0	2	0	4	10	3	10	18	1	**51**
	Isopoda	0	0	0	0	0	0	0	0	1	0	0	**1**
	Carpias sp.	0	0	0	0	0	0	0	0	0	3	0	**3**
	Mithrax sp.*	0	0	0	0	0	0	2	0	0	0	0	**2**
	Epialtus bituberculatus (Milne Edwards, 1834)	0	0	0	0	0	0	1	0	0	0	0	**1**
	Micropanope nuttingi (Rathbun, 1898)	0	0	0	1	0	0	1	0	0	0	0	**2**
	Petrolisthes armatus (Gibbes, 1850)	0	0	0	0	0	0	0	0	0	1	0	**1**
	Pachycheles monilifer (Dana, 1852)	0	0	0	0	0	0	0	0	0	0	2	**2**
	Pachycheles laevidactylus (Ortmann, 1892)	0	0	0	0	2	5	10	9	4	3	2	**35**
	Pycnogonida sp.	2	0	0	0	0	0	0	0	0	0	0	**2**
Mol (9)	Bivalvia sp. 1	0	0	0	1	25	9	3	1	2	1	0	**42**
	Bivalvia sp. 2	0	0	0	1	0	0	0	0	0	0	0	**1**
	Bivalvia sp. 3	0	0	0	0	1	3	0	1	1	1	2	**9**
	Mytilidae sp.*	0	0	0	3	1	2	0	1	1	2	0	**10**
	Sphenia fragilis (Adams & Adams, 1854)	0	0	0	1	0	0	0	0	0	0	0	**1**
	Arca sp.	0	0	0	0	0	0	0	0	0	1	0	**1**
	Gastropoda sp.	0	0	0	0	0	0	0	0	0	1	0	**1**
	Calyptraeidae	1	0	1	0	0	1	0	1	0	3	0	**7**
	Crepidula sp.	0	0	1	1	0	0	0	0	0	0	0	**2**

Continued

Table 1. Continued

	Taxa	January	February	March	May	June	July	August	September	October	November	December	Total
Bry (3)	*Bugula neritina* (Linnaeus, 1758)	1	0	2	3	4	0	0	0	0	0	0	10
	Scrupocellaria aff. *reptans* (Linnaeus, 1758)	0	1	1	7	5	2	1	0	0	1	2	20
	Hippoporina sp.	0	0	1	0	0	0	0	0	0	0	0	1
Ech (4)	*Ophiactis savignyi* (Müller & Troschel, 1842)	1	0	0	0	0	0	1	0	0	0	1	3
	Ophiactis lymani (Ljungman, 1872)	6	0	0	0	0	0	0	0	0	0	3	9
	Amphipholis squamata (Delle Chiaje, 1828)	0	0	0	0	0	0	0	0	0	1	0	1
	*Lytechinus variegatus** (Lamarck, 1816)	0	0	0	0	0	0	0	1	0	0	0	1
Asc (3)	*Didemnum* sp. 1	1	1	2	1	1	0	0	0	0	1	1	8
	Didemnum sp. 2	0	0	2	2	0	1	0	0	0	0	0	5
	Botrylloides giganteum (Pérès, 1949)	0	0	0	0	0	1	0	0	0	0	1	2
Number of specimens		**38**	**3**	**12**	**28**	**42**	**47**	**38**	**26**	**23**	**66**	**26**	**349**

species diversity of the total associated macrofauna was high ($H' = 3$), but the total evenness was low ($J' = 0.4$) (Table 2).

The most abundant higher taxa were Arthropoda (54%), Mollusca (21%) and Bryozoa (9%) (Figure 2), while the most frequent were Arthropoda, Annelida (Polychaeta), Mollusca and Bryozoa, present in 72.2%, 57.4%, 48.2% and 40.7% of sponges, respectively (Figure 3). Chordata (Ascidiacea), Cnidaria (Hydrozoa) and Echinodermata were found less frequently (present in 22.2%, 14.8% and 12.9% of sponges, respectively), while Platyhelminthes, Nemertea and Porifera were found in only 1.8% of specimens (Figure 3). The density of associated individuals was highest in November and June (3.1 and 2.8 individuals cm^{-3}) and lowest in February and January (0.2 and 0.3 individual cm^{-3}). This variation was not significantly different between the dry and rainy seasons (Table 3A).

Juvenile representatives of Crustacea (*Mithrax* sp.), Polychaeta (Sabellidae sp. and Syllidae spp.), Mollusca (Mytilidae sp.) and Echinodermata (*Lytechinus variegatus*) were found living associated with *P. magna*. In addition, pregnant crustacean females were also frequently observed.

Volume

Total sponge volume (i.e. the sum volume of sponges collected each month: Table 2) did not differ between seasons (Table 3B) but varied significantly with both species diversity (H') ($R^2 = 0.43$, df = 10, $P = 0.027$: Figure 4A) and the number of taxa (species richness) ($R^2 = 0.37$, df = 10, $P = 0.04$: Figure 4B), indicating that larger sponges contained a higher variety of taxa and a higher diversity of species. Nonetheless, regression analyses indicated that the total volume each month varied with neither the Pielou evenness index (J') ($R^2 = 0.04$, df = 10, $P = 0.52$: Figure 4C) nor the total number of associated individuals (abundance) ($R^2 = 0.03$, df = 10, $P = 0.56$: Figure 4D).

Seasonality

The periods of lowest and highest richness (February = 4; January = 20, respectively) coincided with the months of lowest and highest diversity (H') (February—$H' = 1.4$; January—$H' = 2.7$, respectively) (Table 2). Abundance (i.e. the number of associated individuals) was lowest in February (only three individuals), while the highest was in November (66 individuals) (Table 1; Figure 5). The evenness of associated macrofauna tended to be high, being highest in February and March ($J' = 1.0$) and lowest in June ($J' = 0.6$) (Table 2). None of these community descriptors differed significantly between the dry and rainy seasons (Table 3C–F).

Seasonal changes in the community of macrofauna associated with *P. magna* were analysed using biplots based on PCA (Figure 6A). The total amount of variation explained by the first two scores (corresponding to the first two principal components) was 56.9%. The PCA biplot did not show a clear seasonal difference between the dry and rainy seasons. Nevertheless, three groups of species were partially distinguished by the analysis:

Group A (formed mainly by the bryozoan *Scrupocellaria* aff. *reptans* (Linnaeus, 1758) and the ascidians *Didemnum* sp. 1 and *Bugula neritina* (Linnaeus, 1758)), which appeared between February and June;

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Table 2. Summary of the ecological data collected each month.

	January	February	March	May	June	July	August	September	October	November	December	Year
Number of species	20	4	9	14	11	12	12	10	8	18	13	50
Number of specimens	38	3	12	28	42	47	38	26	23	66	26	349
Species diversity (*H'*)	2.7	1.4	2.1	2.4	1.5	2.0	2.1	1.8	1.7	2.1	2.4	3.0
Evenness (*J'*)	0.9	1.0	1.0	0.9	0.6	0.8	0.8	0.8	0.8	0.7	0.9	0.4
Total volume of sponges (cm^3)	115	18	8	11	15	38	52	24	12	21	67	381
Density (ind. cm^{-3})	0.3	0.2	1.5	2.5	2.8	1.1	0.7	1.1	1.9	3.1	0.4	0.9

Group B (formed mainly by the mollusc Bivalvia sp. 1 and the crustaceans *Pachycheles laevidactylus* Ortmann, 1892 and *Cymadusa filosa* Savigny, 1816) that appeared from July to November;

Group C (formed mainly by the ophiuroid *Ophiactis lymani* Ljungman, 1872) comprised only one species and was found exclusively in January and December.

Scores of the first component (PC1), which account for 38.7% of the variation, did not differ significantly between the dry and rainy seasons (Figure 6B; Table 4A). However, the scores of the second component (PC2), which account for 18.2% of the variation, were significantly different between these seasons (Figure 6C; Table 4B).

DISCUSSION

Paraleucilla magna exhibited moderate-to-low richness of associated macrofauna (51 species) relative to all other sponge species investigated to date (48 Demospongiae and two Hexactinellida), the latter of which yielded an average of 95.5 associated taxa (±162.2), with a minimum of two and a maximum of 809 taxa (e.g. Westinga & Hoetjes, 1981; Villamizar & Laughlin, 1991; Cuartas & Excoffon, 1993; Klitgaard, 1995; Koukouras *et al.*, 1996; Betancourt-Lozano *et al.*, 1998; Magnino *et al.*, 1999; Çinar *et al.*, 2002; Neves & Omena, 2003; Ribeiro *et al.*, 2003; Abdo, 2007; Huang *et al.*, 2008). In *P. magna*, Crustacea was the most abundantly represented group of associated organisms (54%), followed by Mollusca (21%) and Bryozoa (9%). In other studied sponges, Crustacea was also one of the two most abundantly represented groups, being present in 80% of the sponge species examined, followed by Polychaeta (60%) and Echinodermata (24%). Molluscs were the second most abundant group in *P. magna* (21%); however, this is not a common occurrence, as they have been identified as a dominant group in only a few species of sponges (8% of those examined so far: Long, 1968; Peattie & Hoare, 1981; Klitgaard, 1995; Koukouras *et al.*, 1996). The same pattern occurs with Bryozoa, which was the third most abundant taxon in *P. magna* but is not considered to be among the two most abundant organisms in other studied sponges. However, bryozoans were the second most dominant group (12.8% of the total number of taxa) found in demosponges of the Faroe Islands, north-eastern Atlantic (Klitgaard, 1995) and, as in the present study, Klitgaard (1995) also found that most of the bryozoans were attached to the outer surface of the sponges. Associations between sponges and bryozoans may be related to the fact that sponges may provide suitable substrate to bryozoans in habitats of otherwise limited substrate availability, as noted by Klitgaard (1995).

A study of the associated fauna of the demosponge *Mycale microsigmatosa* Arndt, 1927 was performed at the same location of the present study (Ribeiro *et al.*, 2003). Both *P. magna* and *M. microsigmatosa* exhibit associated

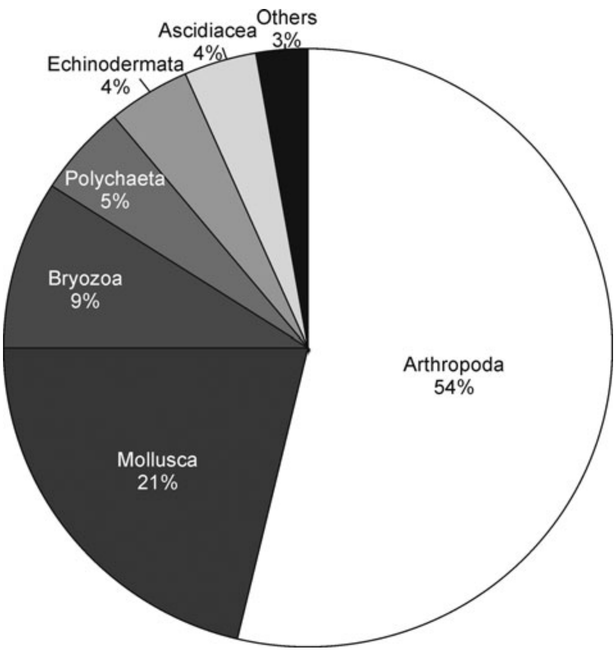

Fig. 2. Proportion of higher taxa associated with *Paraleucilla magna*.

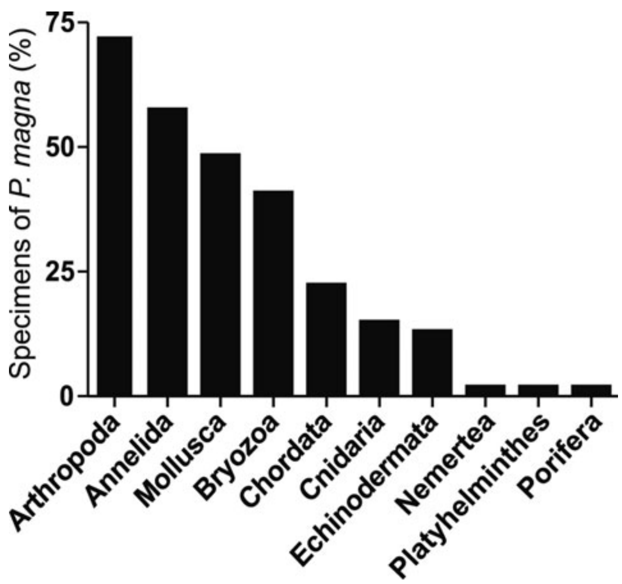

Fig. 3. Percentage of *Paraleucilla magna* specimens hosting each higher taxon.

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Table 3. Summary of the analysis of variance testing the influence of seasonality (dry versus rainy seasons) on community descriptors during the study period.

	df	Sum Sq	Mean Sq	F value	Pr(>F)
(A) Density of associated individuals					
Season	1	0.552	0.5520	0.4402	0.5236
Residuals	9	11.285	1.2539		
(B) Sponge volume					
Season	1	404.600	404.6000	0.3559	0.5655
Residuals	9	10232.800	1137.0000		
(C) Species richness					
Season	1	0.109	0.1091	0.0049	0.9455
Residuals	9	198.800	22.0889		
(D) Number of associated individuals					
Season	1	186.380	186.3800	0.5943	0.4605
Residuals	9	2822.530	313.6200		
(E) Diversity (H′)					
Season	1	0.032	0.03292	0.1850	0.6773
Residuals	9	1.601	0.17797		
(F) Evenness					
Season	1	0.025	0.02579	2.6065	0.1409
Residuals	9	0.089	0.00989		

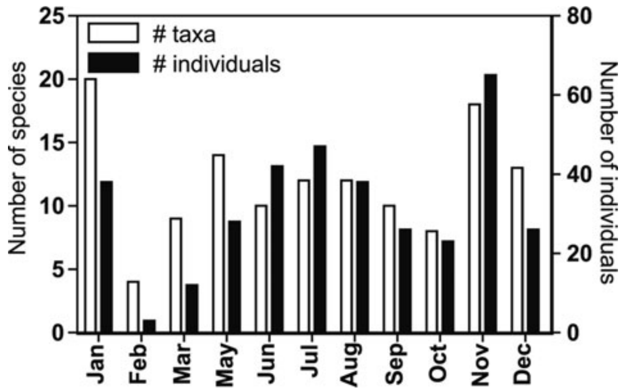

Fig. 4. Monthly variation in the number of species and individuals associated with *Paraleucilla magna*.

macrofauna of similar species richness (51 and 75 species, respectively) and composition. However, the differences observed in taxonomic composition between these two sympatric species can be explained by the different sample sizes of each study: in the present study, we analysed 54 specimens of *P. magna*, while Ribeiro *et al.* (2003) analysed 19 specimens of *M. microsigmatosa*. Species diversity was the same between *P. magna* and *M. microsigmatosa* ($H' = 3$), while evenness was lower in *P. magna* ($J' = 0.4$, versus $J' = 0.7$ for *M. microsigmatosa*). The difference in evenness values between both species may be also due to sampling differences: in the present work several collections throughout the year were made, while Ribeiro *et al.* (2003) made only one collection. The most striking difference between these two species is in the total number of associated individuals (abundance): *P. magna* was associated with 349 individuals (0.9 individual cm^{-3}), while *M. microsigmatosa* was associated with 2235 (13 individuals cm^{-3}). If we consider that both sponges have the same type of aquiferous system (leuconoid), we could expect similar internal canals and, consequently, similar associated macrofauna. Nonetheless, in fact, the atrium of *P. magna* is larger than that of *M. microsigmatosa*, and whereas *P. magna* is massive, *M. microsigmatosa* is an incrustant sponge. In addition, the external surface of *P. magna* is full of folds, while *M. microsigmatosa* has a smoother surface. Despite these morphological characteristics that seem to characterize *P. magna* as a better host, *M. microsigmatosa* is host to more associated organisms. A possible explanation for this difference in macrofauna abundance is the presence of chemicals that might reduce predation in

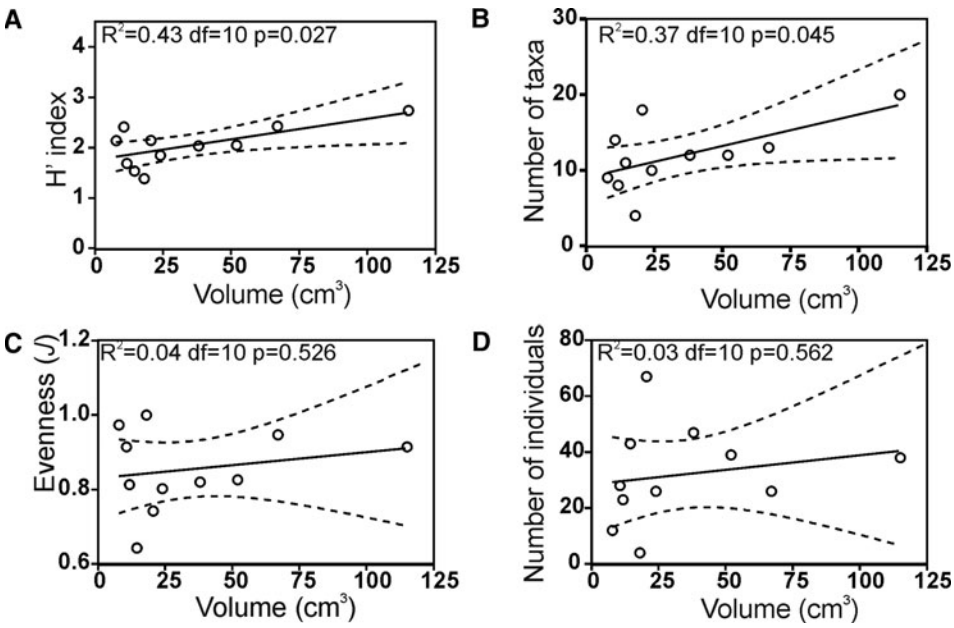

Fig. 5. Quantitative analyses of the macrofauna associated with *Paraleucilla magna*. Linear regression between sponge volume and (A) species diversity (H′); (B) number of taxa; (C) evenness (J′); and (D) number of individuals. The dotted line indicates the 95% confidence intervals.

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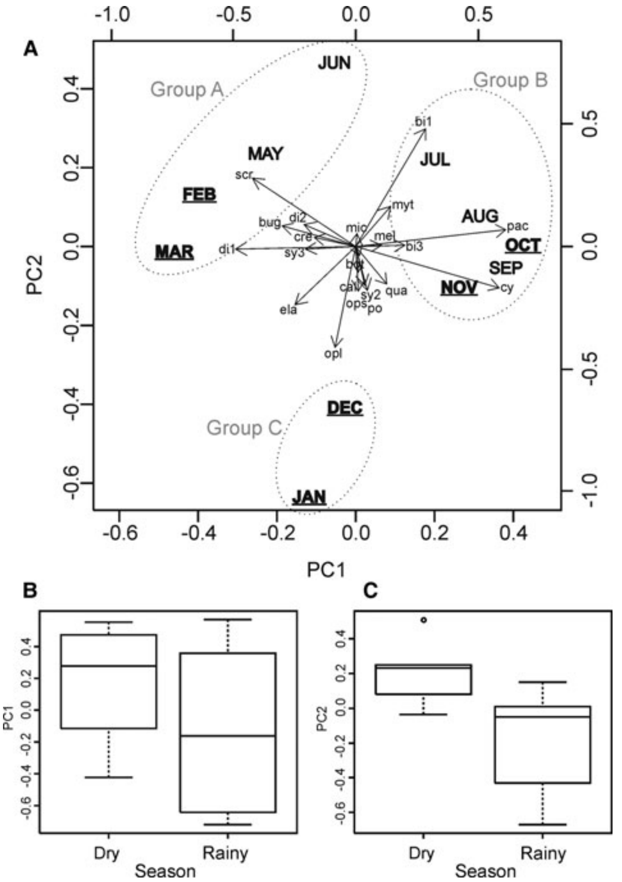

Fig. 6. Principal component analysis (PCA) of the associated fauna of *Paraleucilla magna*. (A) A biplot representation of the PCA showing both observations (months) and variables (species) in the same graph. The left and bottom axes use the unity for observations, while the top and right axes are graduated according to the first two principal components of the original variables. PC1 accounts for 38.7% of the total variation, while PC2 accounts for 18.2%. Months are represented by upper case letters (those of the rainy season are underlined) and species are represented by small characters (bi1, Bivalvia sp. 1; bi3, Bivalvia sp. 3; bot, *Botrylloides giganteum*; bug, *Bugula neritina*; cal, Calyptraeidae; cre, *Crepidula* sp.; cym, *Cymadusa filosa*; di1, *Didemnum* sp. 1; di2, *Didemnum* sp. 2; ela, *Elasmopus ectenicrus*; mel, Melitidae sp.; mic, *Micropanope nuttingi*; myt, Mytilidae sp.; opl, *Ophiactis lymani*; ops, *Ophiactis savignyi*; pac, *Pachycheles laevidactylus*; pod, Podoceridae sp.; qua, *Quadrimaera quadrimana*; scr, *Scrupocellaria* aff. *reptans*; sy2, Syllidae sp. 2; sy3, Syllidae sp.); (B & C) Box plots of the scores of (B) the first principal component (PC1) and (C) the second principal component (PC2) in the dry and rainy seasons. Each box displays the median, upper and lower quartiles of the distribution of sponge volume per month. Box whiskers represent the maximum and minimum range, while empty circles show outliers.

Table 4. Summary of the analysis of variance testing the influence of the two main principal components on the seasonality (dry versus rainy seasons) of the associated fauna during the study period. (Significance codes:* – 0.05).

	df	Sum Sq	Mean Sq	F value	*Pr(>F)*
(A) PC1					
Spp.*season	1	0.2126	0.2126	0.9401	0.3576
Residuals	9	2.0353	0.2261		
(B) PC2					
Spp.*season	1	0.3972	0.3972	5.4382	0.0446*
Residuals	9	0.6573	0.0730		

M. microsigmatosa and, consequently, provide more protection for its associated macrofauna. Although this hypothesis has not been tested, *M. microsigmatosa* does produce a series of compounds, some of which inhibit microorganism proliferation (Compagnone *et al.*, 1999). The potential importance of sponge allelochemicals in influencing the composition and abundance of associated fauna has already been pointed out (Koukouras *et al.*, 1992; Skilleter *et al.*, 2005). A good example can be found in the work of Betancourt-Lozano *et al.* (1998), which describes a significant relationship between inquilinism and the antibiosis activity of *Aplysina fistularis* (Pallas, 1766) in Mexico.

Paraleucilla magna shares with *M. microsigmatosa* at least four species, two of which (the ophiuroids *Amphipholis squamata* and *Ophiactis savignyi*) occur commonly in other sponge species (Table 5). Although echinoderms have been found in only 12.9% of the analysed specimens of *P. magna*, they (particularly Ophiuroidea) are commonly found in demosponges (Wendt *et al.*, 1985; Duarte & Nalesso, 1996; Betancourt-Lozano *et al.*, 1998; Ribeiro *et al.*, 2003; Abdo, 2007) and other benthic organisms, such as bryozoans (Morgado & Tanaka, 2001). Associations of *Ophiactis savigny* and *O. lymani* with marine organisms are apparently common. For example, both species have been described as common epifauna on the tubes of the polychaete *Phyllochaetopterus socialis* Claparède, 1869 (Nalesso *et al.*, 1995), on the octocoral *Carijoa riisei* (Duchassaing & Michelotti, 1860) (Neves *et al.*, 2007), and on algae (Mladenov & Emson, 1988). The frequent association of these ophiuroid species with varied taxa (algae, polychaetes, corals and sponges) may indicate that these associations (including with *P. magna*) are only occasional or opportunistic. These ophiuroids may seek out these organisms only for protection or food (Klitgaard, 1995).

The volume of *P. magna* was positively related only to species diversity and number of taxa (richness). These relationships have already been observed in other sponge species: *S. foetidus* (for species diversity) and *M. microsigmatosa*, *M. angulosa*, *S. foetidus* and *Sphecíospongia vesparium* (Lamarck, 1815) (for richness) (Westinga & Hoetjes, 1981; Duarte & Nalesso, 1996; Çinar *et al.*, 2002; Ribeiro *et al.*, 2003). In *P. magna*, higher volumes can reflect a diverse array of microhabitats inside the sponge, such as more and larger folds, or larger atria and oscula, which could accommodate larger organisms and, consequently, a higher diversity of taxa. On the other hand, no relationship between volume and number of individuals was observed in *P. magna*, and this relationship has also not been observed in several demosponge species (four from the Aegean Sea: Koukouras *et al.*, 1992; and two from Australia: Skilleter *et al.*, 2005). In *P. magna*, large volumes might provide habitat for other species that could then compete with the fauna that live in smaller sponges. The fact that we found associated organisms in a great variety of sponge volumes (from 0.3 cm^3 to 37 cm^3) suggests that this species is rapidly colonized by organisms in the environment.

In the present study, no seasonal variation in community descriptors of the fauna associated with *P. magna* (species richness, number of individuals, species diversity (H') and evenness index (J')) was detected. This lack of seasonal variation can be explained, in part, by the relationship of some of these descriptors to sponge volume (as described above). As neither sponge volume nor the community descriptors

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Table 5. Species associated with *Paraleucilla magna* that have also been identified in association with other sponge species. 1, *Mycale microsigmatosa* (Rio de Janeiro — Brazil; Ribeiro *et al.*, 2003); 2, *Mycale angulosa* (São Paulo — Brazil; Duarte & Nalesso, 1996); 3, *Dysidea fragilis* (in Rio de Janeiro — Brazil; Serejo, 1998); 4, *Topsentia* sp. (southeastern United States; Fiore & Jutte, 2010); 5, *Ircinia campana* (south-eastern United States; Fiore & Jutte, 2010); 6, *Sarcotragus foetidus* (Turkish Aegean coast; Çinar *et al.*, 2002); 7, *Aplysina lacunosa* (Venezuelan Caribbean; Villamizar & Laughlin, 1991); 8, *Sarcotragus fasciculatus* (North Aegean Sea; Koukouras *et al.*, 1985); 9, *Sidonops corticostylifera* (Rio de Janeiro — Brazil; Clavico *et al.*, 2006); 10, *Halichondria panicea* (Menai Strait — UK; Peattie & Hoare, 1981); 11, *Ircinia strobilina* (Bimini — Bahamas; Pearse, 1950); 12, *Geodia macandrewii* (Faroe Islands; Klitgaard, 1995).

Associated species	1	2	3	4	5	6	7	8	9	10	11	12
Elasmopus pectenicrus	x											
Quadrimaera quadrimana			x									
Dulichiella appendiculata			x	x	x							
Halosydnella brasiliensis	x											
Amphipholis squamata	x	x						x		x		x
Ophiactis lymani		x										
Ophiactis savignyi	x	x				x	x		x		x	

exhibit variation between the dry and rainy seasons (see Table 2), the absence of any seasonal trend could be expected.

Although the PCA biplot (Figure 6A) suggests no seasonal variation between the dry and rainy seasons, the second component (PC2) scores differed significantly between seasons. This latter result indicates that some environmental change (in features such as salinity, temperature or food availability) might influence the composition of the associated fauna community. However, the causes of variation explained by the first component (PC1) are unknown and not likely to be correlated with season. On the other hand, we observed three groups of species that occupied *P. magna* in temporal succession (Groups A, B and C). The establishment of these groups may reflect the life cycle of the associated organisms.

We frequently found pregnant crustacean females and juveniles of several taxa (molluscs, crustaceans, echinoderms and polychaetes) inhabiting *P. magna*, that probably used their host as a temporary shelter during vulnerable periods of their life cycle (i.e. reproductive or juvenile stages). This kind of relationship can be characterized as opportunistic. Ribeiro *et al.* (2003) and Abdo (2007) also found pregnant females, juveniles or reproductively active individuals associated with *M. microsigmatosa* and two *Haliclona* species in Brazil and Australia, respectively.

These findings suggest that sponges may be important shelters during some stages of the life cycle of many invertebrates, enhancing survival. All of these aspects regarding the role of sponges in the community reiterate a previous proposal (Cerrano *et al.*, 2006): namely that sponges are important reservoirs of biodiversity and that the phylum Porifera should be seriously considered in conservation programmes.

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