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Diversity and seasonal fluctuations of microsymbionts associated with some scleractinian corals of the Picãozinho reefs of Paraíba State, Brazil

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Abstract. Monthly changes were observed in the densities of zooxanthellae of the corals *Montastraea cavernosa*, *Mussismilia harttii*, *Mussismilia hispida* and *Siderastrea stellata* from June/2007 to June/2008 on Picãozinho Reef, Joao Pessoa - PB, Brazil. Lowest values of the densities of zooxanthellae were observed in July and August 2007 and the highest in September and October 2007. The mitotic indices of zooxanthellae showed highest percentages in *M. hispida* and the lowest in *S. stellata*. The diameter of zooxanthellae showed significant differences between the coral species *M. hispida* and *M. harttii* during the study period and, between seasons for *M. hispida*. In addition to zooxanthellae, diatoms, cyanobacteria, and nematodes were also found among the microbiota associated with the corals studied. Significant variations in the concentrations of microsymbionts were observed during the different seasons only for *S. stellata*. Many of such organisms could be opportunistic and their abundance and diversity are associated with the mucus production. As the coral species are very sensitive to environmental alterations such microsymbionts can be efficient indicators of the health of corals together with the zooxanthellae being their study important.

Key words: zooxanthellae, microsymbionts, scleractinian corals, Brazilian coral reefs

Resumen. Diversidad y variación estacional de los microsimbiontes asociados con algunas especies endémicas de corales de los arrecifes Picãozinho Paraíba, Brasil. El estudio mostró la existencia de cambios mensuales en las densidades de zooxantelas alojados en los corales de *Montastraea cavernosa*, *Mussismilia harttii, Mussismilia hispida* y *Siderastrea stellata*, de los arrecifes Picãozinho, João Pessoa - PB, durante el periodo de Junio/2007 a Junio/2008. Los valores más bajos en las densidades de zooxantelas acorrerán en julio y agosto de 2007 y los valores más altos en septiembre y octubre de 2007. Las tasas de la división celular de zooxantelas mostraron porcentajes más altos en *M. hispida* y la menor en S. *stellata*. El diámetro de las zooxantelas mostró diferencias significativas entre las especies de coral *M. hispida* y *M. harttii* durante el período de estudio y, entre las estaciones en *M. hispida*. Además de las zooxantelas se encontraron diatomeas, cianobacterias y nematodos que estaban presentes en la microbiota de los corales estudiados. Variaciones significativas en la concentración de estos microssimbiontes fueron observados entre las estaciones para *S. stellata*. Muchos de estos organismos podrían ser oportunista y su abundancia y diversidad están asociados con la producción de moco. Como las especies de coral son muy sensibles a las alteraciones ambientales tales microsimbiontes pueden ser indicadores eficientes de la salud de los corales.

Palabras clave: zooxantelas, microssimbiontes, corales escleractínidos, arrecifes de coral brasileros

Introduction

Brazilian reef ecosystems are the only reefs encountered in the southern Atlantic. They extend for approximately 3000 km in a discontinuous manner between the states of Maranhão and Bahia (Castro & Pires 2001, Leão *et al.* 2003) and are divided into four geographical regions: Northern, Northeastern, Eastern, and Southern. The northern coast of Brazil is greatly influenced by high-volume river flows containing large amount of suspended sediments (especially from the Amazon River) and the low diversity of the coral fauna found there is due, in large part, to the high turbidity of the waters. The northeastern coast, on the other hand, particularly off the shores of Bahia State at Abrolhos, is a very rich region in terms of reefs and the coral fauna (Spalding *et al.* 2001, Leão *et al.* 2003, Maida & Ferreira 2004, Leão & Kikuchi 2005).

Although Brazilian reefs are poorer in coral species than Caribbean or Indo-Pacific reefs they have high levels of endemism of archaic forms that originated before the Tertiary period, and are therefore considered a distinct biogeographical province (Laborel, 1970, Leão *et al.* 2003, Leão & Kikuchi 2005).

Of the 18 species of scleractinian corals that occur in Brazil, six are endemic: *S. stellata*, *Mussismilia harttii*, *Mussismilis hispida*, *Mussismilis braziliensis*, *Favia gravida*, and *Favia leptophyla* (Castro & Pires 2001, Santos et al., 2004 a,b; Amaral *et al.* 2007). Genera such as *Mussismilia* play important role in reef reconstruction in areas such as Abrolhos (Leão *et al.* 1988), while species such as *Siderastrea stellata* are conspicuous components of shallow water reefs and can be found growing under rather extreme conditions (such as tidal pools). There are other taxa that construct shallow-water reefs and are conspicuous in the coastal waters of Brazil that have zooxanthellae associate with their tissues, giving a total of about 20 species for the country (Leão *et al.* 2003).

Scleractinian corals from Brazil have been studied in terms of their taxonomy (Amaral 1994, Amaral *et al.* 2007), deposition of calcium carbonate (Mayal *et al.* 2009), reproduction (Neves & Pires 2002), cover and recruitment (Castro *et al.* 2006); molecular biology (Neves *et al.* 2008, Nunes *et al.* 2008), bleaching (Castro & Pires 1999, Costa *et al.* 2001a, Leão *et al.* 2008, Poggio *et al.* 2009), the presence of nitrogen fixing bacteria (Chimetto *et al.* 2008), and the diseases that affect them (Francini-Filho *et al.* 2008). Studies focusing on their symbiotic relationships with zooxanthellae and other microsymbionts are still relatively scarce and were published only during the first decade of the present century (Costa *et al.* 2001a,b, Costa & Amaral 2002, Costa *et al.* 2004a,b, Costa *et al.* 2005, Costa *et al.* 2008a,b). Despite their importance to the economy and health of reef ecosystems (Muller-Parker et al. 1988), few studies have focused on the association between symbiotic dinoflagellates and corals in Brazil, where almost half of the scleractinian species are endemic

Zooxanthellae have important roles in maintaining coral health and contribute to reef productivity (Muscatine 1974, Muller-Parker & D´Elia 1997) but commonly demonstrate variations in their densities, mitotic indices, and in the concentrations of their photosynthetic pigments during the year (Stimson 1997, Fagoonee *et al.* 1999, Brown *et al.* 2000, Fitt *et al.* 2000, Costa *et al.* 2004b, 2005) that reflect alterations in the light environment, water temperature (Brown *et al.* 2000, Warner *et al.* 2002, Costa *et al.* 2004b, 2005, Rodolfo-Metalpa *et al.* 2006, Hoogenboom *et al.* 2010), and/or the concentrations of dissolved nutrients (Fitt *et al.* 1993, Stimson 1997, Fagoonee *et al.* 1999).

The present work describes annual cycles of four coral species (three of them endemic species). Studies focusing on such approaches have been conducted on scleractinian coral growing along the Brazilian coast (Costa *et al.* 2004b, 2005) as well as on zoanthids and calcareous hydroids (Amorim *et al.* 2011), and in some cases their ranges are severe enough to result in bleaching and the appearance of diseases (Costa *et al.* 2001a), although the available data is still insufficient to establish patterns or to understand the mechanisms that trigger these changes.

Corals can host a very diverse microbiota in addition to zooxanthellae (Piyakarnchana *et al.* 1986, Costa *et al.* 2001b, 2004a). Many organisms that make up part of planktonic communities are also found on the surfaces of corals (Paul *et al.* 1986, Wild *et al.* 2004) and in the interstitial spaces of the limestone walls of the scleractinian (Ferrier-Pagès *et al.* 1998). These findings merit more intense investigation, as the precise roles of these organisms and their relationships with their hosts are not yet fully understood (Costa *et al.* 2001b, 2004a).

Published studies have reported diatoms, cyanobacteria, parasites, and micro-crustaceans associated with Brazilian corals (Costa *et al.* 2001b, 2004a), as well as with zoanthids and the calcareous hydroids *Millepora alcicornis* (Amorim *et al.* 2011). The present work describes annual cycles of the zooxanthellae hosted by four species of scleractinian coral as well as the presence of other microsymbionts found associated with them on the Picãozinho coastal reefs at João Pessoa, Paraíba State in northeastern Brazil.

Among the corals studied in this work, the *Mussismilia* genus plays an important role in the construction of some Brazilian reefs, such as those of Abrolhos region (Bahia State), where these corals are the main constituent of reef foundations (Leão *et al.* 1988). *S. stellata* is the most conspicuous species, although it is not prominent in the formation of Brazilian reefs. *Montastrea cavernosa* is the only species of *Montastrea* found in all Brazilian reefs, except of the Cape of São Roque reef, Northern Brazil (Castro & Pires, 2001), although this species occurs in other coral reefs around the world. There are several works on planktonic and benthic marine diatoms in Brazil (Sassi 1987, Silva-Cunha & Eskinazi-Leça 1990, Moreira-Filho *et al.* 1999), however, there is still a lack of studies on microsymbionts of marine invertebrates, especially those associated with corals, of Brazilian seawater. The data obtained in this research might be useful to characterize the corals health and relationships between corals and their microsymbionts.

Materials and Methods

Samples collections

Monthly collections were made on the Picãozinho reefs (06º42'05"-7º07'30''S and 34º48'37''- 34º50'00"W) João Pessoa, Paraíba State, Brazil, during the period between June/2007 and July/2008. Four coral fragments (10 cm ϕ) of each species were harvested (using a hammer and chisel) from colonies of *Siderastrea stellata* Verriil, 1868, *Montastraea cavernosa* (Linnaeus, 1767), *Mussismilia harttii* (Verrill, 1868), and *Mussismilia hispida* (Verrill, 1868). The samples were collected at 2 m depth through free-diving, transferred to hermetic plastic bags filled with seawater and transported to the Laboratory of Reef Environments and Microalgae Biotechnology of the Federal University of Paraiba. The coral fragments were obtained from the colonies that were at least at 2 m distance from each other, in order to avoid collection of clones.

The sea surface temperatures (±0.1 ^{o}C), using a Watanabe Keiki reversion thermometer), salinity (portable refratometer), material in suspension (gravimetric determinations), and dissolved oxygen (using the Winkler technique, following Parsons and Strickland, 1963) measurements were taken each month during the field samples. Rainfall data for the study area was obtained from the Agência Executiva of Gestão das Águas do Estado da Paraíba (AESA-PB): http://www.aesa.pb.gov.br/

Laboratory analyses

Coral tissues were extracted from each sample using a high-pressure jet of water (waterpik®), the extracted volume was registered, and the materials were subsequently homogenized mechanically and fixed in Lugol 10% following the protocols of Costa *et al*. (2008a). The samples were subsequently examined using a light microscope to determine zooxanthellae population densities, mitotic indices, and cellular diameters.

Zooxanthellae densities were analyzed using a Fuchs Rosenthal chamber and expressed in terms of the numbers of cells per square centimeter of the coral skeleton, following the techniques of Marsh (1970) and the protocols of Costa *et al*. (2008a). The other components of the microbiota were analyzed for logistics reasons only for samples of *S. stellata*, *Mussismilia harttii*, and *Montastraea cavernosa* that were collected during the period between September/2007 and June/2008. The qualitative and quantitative analyses of these microorganisms were made using a Sedgwick-Rafter chamber. The representatives of the microbiota were photographed between slides and cover slips at various magnifications using a Pixera digital camera coupled to a microscope. The diatoms were identified following Cupp (1943), Hendey (1964), Ricard (1987), and Silva-Cunha & Eskinazi-Leça (1990). The species names were updated based on the WORMS (World Register of Marine Species) database, available at http://www.marinespecies.org/about.php.

Statistical analyses

All statistical analyses were carried out using Statistica7.0 for Windows software, at 5% level of significance. The homoscedasticity of the variances of all zooxanthellae parameters analyzed were confirmed utilizing the Levene's test and the Shapiro normality test. The mean of the population densities and mitotic index of the zooxanthellae measured over the year were compared by Kruskal-Wallis test, and the parameters of the rainy (June and July/07, and March, April, May, and June/08) and dry (August, September, October, November and December/07, and January and February/08) seasons were compared by Mann-Whitney test. The means of the cellular diameters of the zooxanthellae and the densities of other microorganisms associated with the species of coral measured over the year were compared by ANOVA, and between dry and rainy seasons by Studente t-test. Spearman Correlation test were used to determine whether there were significant correlations between the environmental data and zooxanthellae parameters. All statistical analyses followed Sokal & Rohlf (1983).

Results

Variations were observed in the densities of the zooxanthellae in all of the corals examined, with the highest densities being recorded between October and December/2007 and the lowest values between July and August/2007 and February to June/2008; the coral *Mussismila harttii* consistently demonstrated the highest monthly averages of densities of zooxanthellae (Fig. 1). Statistical analysis indicated that only *M. harttii* did not demonstrate significant differences in zooxanthellae densities during the study period (Kruskal-Wallis test; H=0.000; p=1.00). The comparisons of the rainy and dry seasons indicated that all of the coral species had higher concentrations of zooxanthellae during the dry period and lower concentrations during the rainy period space, but that only *S stellata* did not demonstrate significant differences in zooxanthellae densities during the rainy and dry seasons (Mann-Whitney test, U=238.00; p=0.07; Fig. 2).

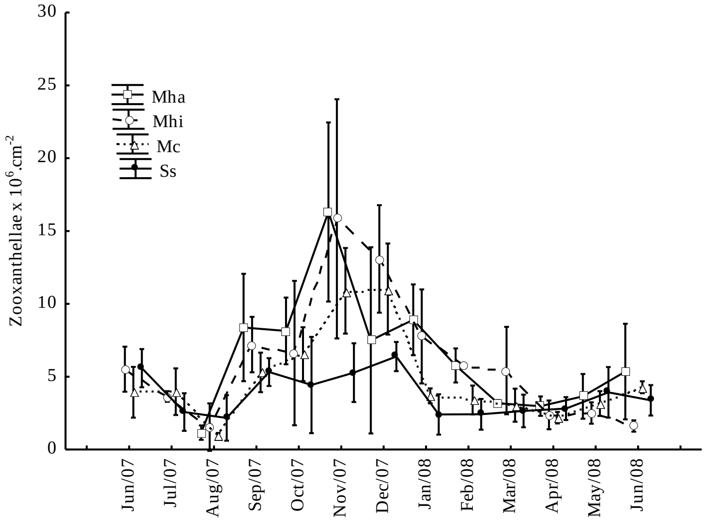

Figure 1. Average monthly densities of zooxanthellae hosted by four coral species studied during the period between June/2007 and June/2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

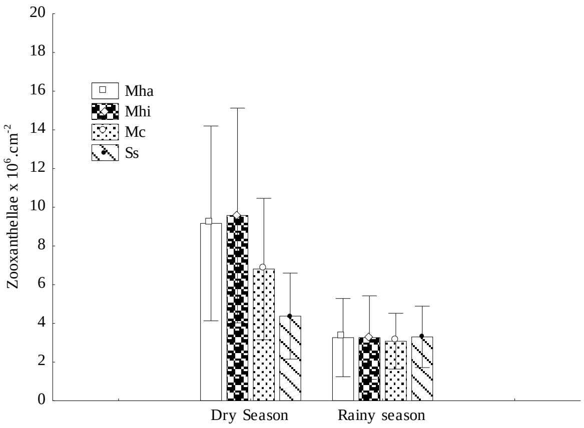

Figure 2. Average values of the densities of the zooxanthellae hosted by four coral species collected in the dry and rainy seasons of the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

The mitotic index of the zooxanthellae likewise varied during the study period, with *M. hispida* having the highest mitotic index of the zooxanthellae (9.18%) and *S. stellata* the lowest (3.06%). All coral species studied showed significant differences in this parameter during the study period (Kruskal-Wallis test, H=0.000; p=0.001; Fig. 3). When the data were analyzed within each of the two seasons, only *M. harttii* demonstrated significant differences in zooxanthellae mitotic indices, with highest values in the rainy season (9.59%) and lowest in the dry season (7.30%) (Mann-Whitney test; U=152.00; p=0.03; Fig. 4).

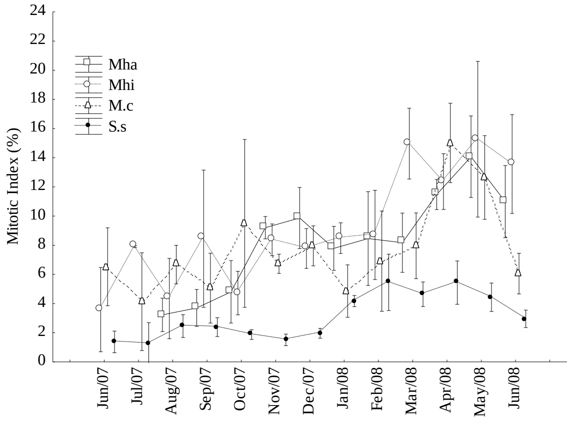

Figure 3. Average monthly values of the mitotic indices of the zooxanthellae hosted by four coral species studied during the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

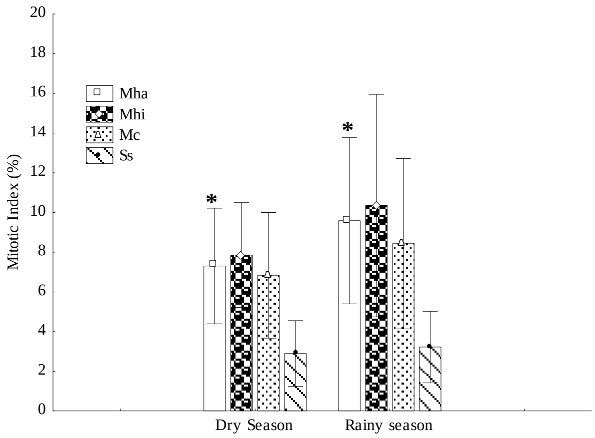

Figure 4. Average values of the mitotic indices of the zooxanthellae hosted by four coral species collected in the dry and rainy seasons of the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

Zooxanthellae cell diameters were significantly larger in *S. stellata* (10.82 ± 0.67 µm) and significantly smaller in *M. harttii* (10.37 ± 0.52 µm) (ANOVA and Tukey test; df=144.0; F=3.51; p=0.01). Significant differences in zooxanthellae cell diameters during the study period were only observed in the corals *M. harttii* (ANOVA; df=30.0; F= 12.45; P=0.00), and *M. hispida* (ANOVA; df=26.0; F= 6.77; p=0.00; Fig. 5); these two species had significantly smaller zooxanthellae diameters during the months of September, October, and November/2007 than during the rest of the study period. *M. hispida* was the only species to show significant differences in zooxanthellae diameters during the two climatic seasons, with the largest diameters being observed during the rainy season (11.1± 0.5 µm) and the smallest during the dry season (10.2 ± 0.6 µm) (Student *t*-test; df.=34.0; t= 4.43; P = 0.00; Fig. 6).

The environmental variables in the study area (suspended material, salinity, surface water temperature, dissolved oxygen, and rainfall) demonstrated monthly fluctuations (Fig. 7) that significantly affected zooxanthellae population densities, mitotic indices, and cell diameters in the corals studied (Spearman Correlation test, p< 0.05; Table I). Rainfall had a significant inverse effect on cell concentrations of zooxanthellae and a positive effect on the percentage of cells undergoing division – with the highest rainfall rates (June to August/07 and May/08) coinciding with the lowest concentrations of zooxanthellae and the highest mitotic indices (Table I and Figs. 1 and 3). The cell diameters of the zooxanthellae hosted by *M. hispida* and *S. stellata* demonstrated strong and significant inverse relationships with salinity and dissolved oxygen (Spearman Correlation test, p< 0.05; Table I). Other variables, such as surface water temperature and material in suspension, significantly influenced the cell diameters of the zooxanthellae found in *M. cavernosa* and *S. stellata* (Spearman Correlation test, p< 0.05; Table I).

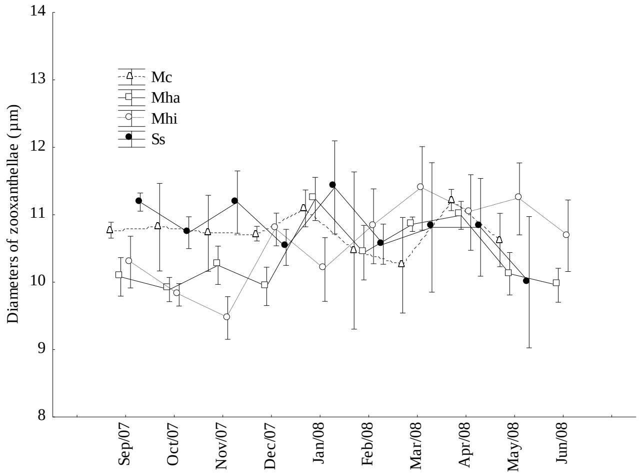

Figure 5. Average monthly values of the cell diameters of the zooxanthellae hosted by four coral species studied during the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, M.c= *Montastraea cavernosa*; S.s= *Siderastrea stellata*).

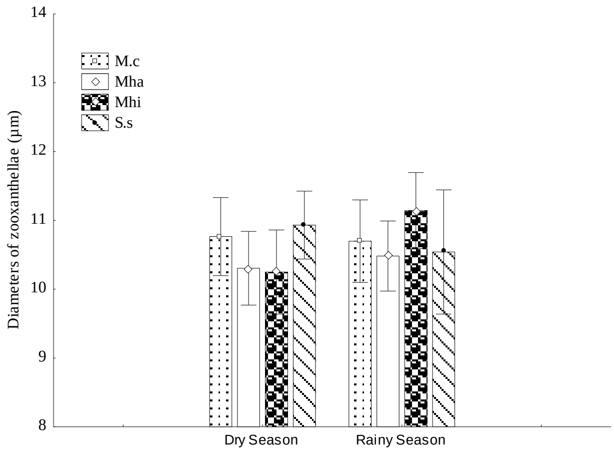

Figure 6. Average values of the cell diameters of the zooxanthellae hosted by four coral species collected in the dry and rainy seasons of the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

In addition to zooxanthellae, a number of other different microorganisms were encountered in the tissues of the corals studied here. The microbiota observed included cyanobacteria, diatoms, and nematodes, with the latter having the greatest representation in all of the corals examined (Fig. 8). Our data indicated non-significant fluctuations in the densities of these other microorganisms associated with three species of coral during the study period (ANOVA, p> 0.05; Fig. 9); significant variations in the densities of the other microsymbionts were seen during the two climatic seasons only in the coral species *Siderastrea stellata* (Student *t*-test; df=8.0; t= -2.87; p= 0.02; Fig. 10).

In general, inverse relationships could be observed between zooxanthellae densities and the quantities of other microsymbionts in the tissues of the coral species studied here, with the highest values of zooxanthellae densities being correlated with the lowest numbers of microsymbionts during the annual cycle as well as during the dry and rainy seasons (Figs. 1, 2, 9, and 10). In case of *Siderastrea stellata*, the higher density of zooxanthellae was observed at dry season and lower at rainy season, however, other microssymbionts showed inverse dynamics. The similar relationships between zooxanthellae and other microsymbionts were observed in *Montastraea cavernosa*, and *Mussismilia harttii.*

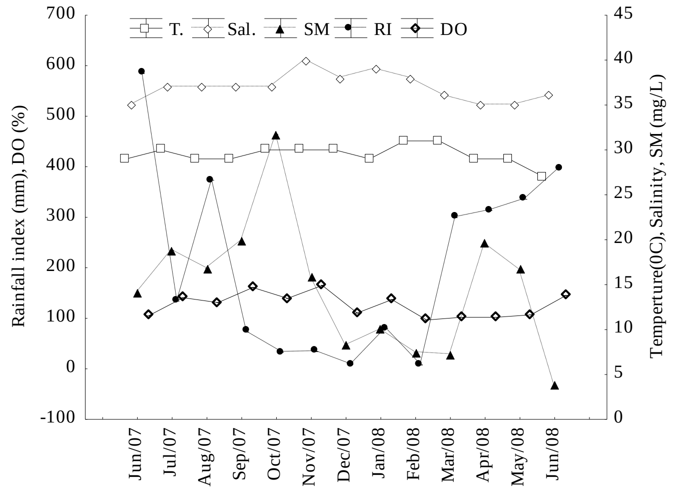

Figure 7. Average monthly values of environmental variables in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil, during the period between June/2007 and June /2008. (T= Surface water temperature; Sal.= Salinity; DO = Dissolved Oxygen; SM = Suspended material; RI = Rainfall Index).

Table I. Spearman Correlations between the environmental variables and the zooxanthellae variables in four coral species studied during the period between June/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (T= Surface water temperature; Sal. = Salinity; DO = Dissolved Oxygen; SM = Suspended Material; RI = Rainfall Index; Den= Zooxanthellae densities; Dia = Zooxanthellae diameters; MI= Mitotic Index; Mha= *Mussismilia harttii*, Mhi= *Mussismilia hispida*, Mc= *Montastraea cavernosa*; Ss= *Siderastrea stellata*).

	Correlation coefficient (*P < 0.05, n=34) for:				
	T (^{0}C)	Sal.	DO (Mg/L)	SM (Mg/L)	RI (mm)
Den-Mha	0,17	0,59*	0,49*	0,04	-0,52*
Den-Mhi	0,45*	0,61*	0,19	-0,10	-0,63*
Den-M.c	0,22	0,44*	0,46*	-0,02	-0,49*
Den-Ss	-0,07	0,02	0,21	0,05	-0,10
MI-Mha	-0,13	-0,32*	-0,27	-0,38*	0,18
MI-Mhi	-0,01	-0,23	-0,17	-0,29*	0,08
MI-Mc	0,01	-0,37*	-0,36*	0,08	0,08
MI-Ss	-0,01	-0,19	-0,52*	-0,28*	0,02
Dia-Mha	-0,03	-0,01	-0,25	-0,32	0,37*
Dia-Mhis	0,11	-0,64*	-0,73*	0,38*	0,58*
Dia-Mc	-0,37*	0,00	0,14	0,26	-0,02
Dia-Ss	-0,06	0,33	0,39*	0,02	-0,21

Discussion

Monthly variations were observed in the environmental variables examined, with some of them being clearly associated with the regional rainfall and the annual temperature cycle. The annual temperatures of the surface water and rainfall demonstrated significant relationships with monthly variations of the zooxanthellae, suggesting synchronicity between those parameters. Similar data were reported by Costa *et al.* (2005) for these same species during the years 2002 and 2003 and, by Amorim *et al*. (2011) for the calcareous hydroids *Millepora alcicornis* in this same environment. Sassi (1987) discussed the effective participation of these parameters in the seasonal dynamics of the phytoplankton on the Cabo Branco reefs located to the south of the present study area. Other authors, such as Verde & McCloskey (1998), Fitt *et al.* (2000), Rodolfo-Metalpa *et al.* (2006), and Hoogenboom *et al.* (2010) likewise noted the influence of environmental parameters on the behavior of zooxanthellae within host tissues.

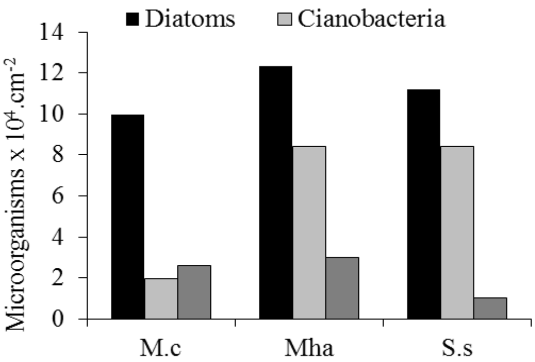

Figure 8. Average values of the other microorganisms (without zooxanthellae) associated with three species of corals analyzed during the period between September/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (M.c= *Montastraea cavernosa*; Mha= *Mussismilia harttii*, S.s= *Siderastrea stellata*).

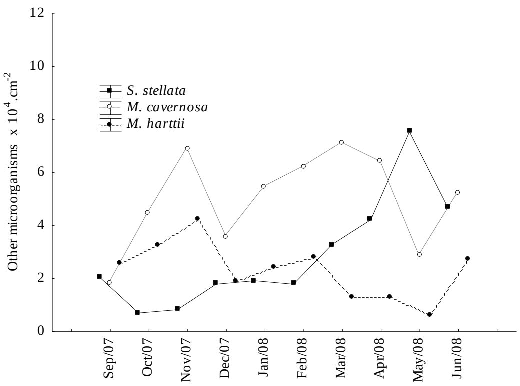

Figure 9. Average monthly values of the other microorganisms (without zooxanthellae) associated with three species of corals analyzed during the period between September/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil.

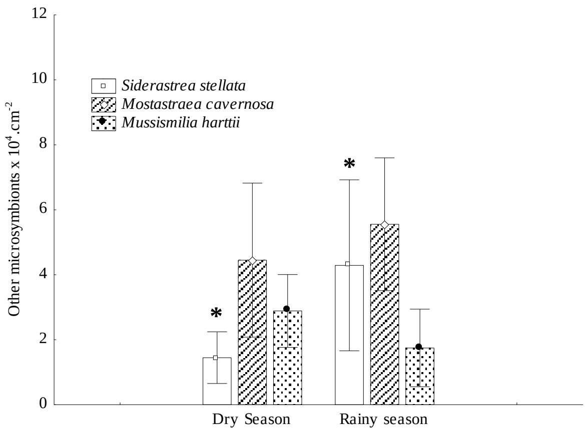

Figure 10. Average densities of the other microsymbionts (without zooxanthellae) hosted by three species of corals analyzed during the period between September/2007 and June /2008 in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil. (*=differences not statistically significant)

A total of 11 diatoms taxa were found, distributed among 11 genera and eight species (Table II), most of them being members of the Order Bacillariales. The greatest diversity of diatoms was observed in *Siderastrea stellata*. The genera *Amphora, Grammatophora, Licmophora, Navicula,* and *Nitzschia* were encountered in all four of the coral species studied (Table II). Five taxa were encountered in all of the coral species, with the genus *Navicula* and the species *Amphora angusta* being the most frequently encountered taxa in all the corals examined.

Table II. Microsymbionts (without zooxanthellae) associated with the scleractinian corals in the Picãozinho reefs at João Pessoa, Paraiba State, Brazil, studied during the period between September/2007 and June/2008.

Microorganisms	Corals species		
	M. harttii	*M. cavernosa*	*S. stellata*
Amphora sp	X	X	X
Cocconeis scutellum			X
Coscinodiscus sp			X
Grammatophora marina	X	X	X
Licmophora gracilis	X	X	X
Melosira sp			X
Navicula spp	X	X	X
Nitzschia sigma	X	X	X
Surirella sp		X	X
Thalassionema nitzschioides			X
Oscillatoria sp		X	X
Nematodes not identified			X

The observed increases in zooxanthellae densities during the months following the rainy season may be associated with the greater availability of nutrients in the water, although the water becomes very turbid during the rainy season and the high sedimentation may interfere with reef development. The existence of coral species in regions with high water turbidity in northeastern Brazil (especially during the rainy season) presents the challenge of explaining their success under what would otherwise appear to be extremely adverse environmental conditions (Mayal *et al.* 2009).

The distinct differences in the densities and mitotic indices of zooxanthellae observed among the different coral species and between the different months suggest that the host corals can control symbiont densities according to variations in local environmental conditions, as was suggested by Davy *et al.* (1997), Fagoonee *et al.* (1999), Costa & Amaral (2002), Costa *et al.* (2005), among others. Factors that can influence zooxanthellae cell division include the availability of sufficient space (Baghdasarian & Muscatine 2000) and the availability of nutrients derived from the host species – including nitrogen (Falkowski *et al.* 1993, Muscatine *et al.* 1989, Fitt *et al*. 1993) and possibly carbon (Douglas 1994).

The diameters of the zooxanthellae of *S. stellata* and *M. harttii* have shown significant differences, however, it should be pointed out that these differences were very discrete suggesting similarities in cell volumes and carbon content of zooxanthellae in the two coral species. Zooxanthellae diameter measurements registered in this study contrast with data obtained for zoanthids. A number of authors have reported that sizes of the zooxanthellae vary according to their host coral species (Shoenberg & Trench 1980, Costa & Amaral 2002).

The presence of a wide diversity of other microsymbionts living in association with the corals examined here (in addition to the zooxanthellae) corroborate findings made in other scleractinian (Piyakarnchana *et al.* 1986, Costa *et al.* 2001b, Costa *et al.* 2004a), in the zoanthid *Palythoa caribbaeorum*, and in the calcareous hydroid *Millepora alcicornis* (Amorim *et al*. 2011), indicating that their presence is more common than commonly imagined. Additionally, the observed monthly fluctuations in the densities of this parameter, demonstrated that environment conditions influence the behavior of the other microsymbionts as they do for zooxanthellae density. It also appears that the zooxanthellae and/or the hosts determine the densities of the other microsymbionts as different relationships were observed between the densities of the zooxanthellae and the other microsymbionts in all of the coral species examined during the nine-month study period and during the dry and rainy seasons.

The roles of other microsymbionts within their hosts are not yet well understood, as many of them appear to be epibionts, and possibly opportunistic (Costa *et al.* 2001b, 2004a). It has been observed that they are more diverse and more abundant in cnidarians that produce significant quantities of mucus (such as in *S. stellata* and *Palythoa caribaeorum*), and it is possible that these organisms are actually captured in the mucus (together with other particles of organic matter) as water currents are driven over the surface of the coral by the cilia. Mucus is liberated in such quantities that it is the dominant form of organic material surrounding the reefs (Wild *et al.* 2004).

In addition to the zooxanthellae and these other microorganisms, corals can host still bacteria and viruses. Many of these organisms can be considered symbionts and may have important roles in maintaining healthy coral colonies.

As these coral reef organisms can tolerate only narrow range of environmental conditions and are thus very sensitive to environmental alterations (Mayal *et al.* 2009), these microsymbionts (together with the zooxanthellae) can be efficient indicators of the health of corals and of other cnidarians, and studies of these organisms may lead to important insights into reef conditions.

All of the diatoms encountered in the present study are common along the Brazilian coast (where they occur as epibenthic organisms or in the plankton) – but many have not yet been identified and additional studies focusing on their taxonomy will be very important. We still far from fully understand the direct causes of the constant seasonal fluctuations in the quantities of these microsymbionts, host ecology, and host strategies for adapting to environmental changes.

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