

# BENTHIC MARINE ALGAE OF THE CORAL REEFS OF BRAZIL: A LITERATURE REVIEW

Marcia Abreu de Oliveira Figueiredo<sup>1</sup>, Paulo Antunes Horta<sup>2</sup>, Alexandre de Gusmão Pedrini<sup>3</sup> & José Marcos de Castro Nunes<sup>4</sup>

<sup>1</sup> Programa Zona Costeira, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rua Pacheco Leão 915. CEP: 22460-030. Rio de Janeiro, Brasil.

<sup>2</sup> Departamento de Botânica, Centro de Ciências Biológicas, Universidade Federal de Santa Catarina, CEP: 88010-970. Florianópolis, Santa Catarina, Brasil.

<sup>3</sup> Departamento de Biologia Vegetal, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, Pavilhão Haroldo Lisboa da Cunha, sala 525/1. CEP: 20550-013, Rio de Janeiro, Brasil.

<sup>4</sup> Departamento de Botânica, Instituto de Biologia, Universidade Federal da Bahia, Campus Universitário de Ondina, Rua Barão de Geremoabo S/Nº. CEP: 40170-110, Salvador, Bahia, Brasil.

E-mails: <sup>1</sup> mfigueir@jbrj.gov.br; <sup>2</sup> pahorta@uol.com.br; <sup>3</sup> pedrini@uerj.br; <sup>4</sup> jmcnunes@ufba.br

## ABSTRACT

In Brazil, algae in coral reef environments can be found from Maranhão to Bahia State and there are today around 700 taxa, of which 78% are found on reef formations. The Rhodophyta are among the most common taxa found. Corallinales are the least studied group, in spite of their role in the formation and maintenance of Brazilian coral reefs. The species richness of algae on coral reefs is low in comparison with other coastal habitats, but there is an abundance of turf and fleshy macroalgae on certain parts of the coastal reefs. *Halimeda* spp., *Dictyota* spp., *Dictyopteris* spp., *Hypnea* spp., *Gracilaria* spp., *Gelidium* spp. and *Sargassum* spp. are some of the most conspicuous algae, while *Caulerpa* and *Udotea* and seagrasses are frequently found on unconsolidated sandy bottoms. Benthic marine algae are important components of shallow coral-reef communities in the Atlantic and they can be regarded as major competitors to corals. Over the last two decades, numerous cases of phase shifts from coral to algal predominance over coral reefs were reported worldwide. These reports coincide with the increasing concern with reef degradation, mainly attributed to anthropogenic nutrient enrichment and overfishing. In Brazil the effects of eutrophication over coral reef dynamics are only recently being assessed, and crucial basic information is still lacking. The exploitation of marine algae, mainly of *Gracilaria*, is also recent in Brazil. Macroalgae growth in some disturbed Brazilian reefs were associated with grazing reduction caused by overfishing or eutrophication. Rapid assessments of coral reef flora are needed in order to generate reliable information for environmental monitoring and to reinforce the legislation protecting Brazilian reefs.

**Keywords:** Algae, coral reefs, diversity, ecology, conservation.

## RESUMO

**ALGAS MARINHAS BENTÔNICAS EM RECIFES DE CORAL BRASILEIROS: UMA REVISÃO BIBLIOGRÁFICA.** No Brasil, algas em recifes coralíneos ocorrem do Maranhão ao estado da Bahia e apresentam cerca de 700 táxons, dos quais 78% são encontrados ao longo de formações descontínuas. Táxons de rodofíceas estão entre os mais comuns. Corallinales é o grupo menos conhecido, apesar de desempenhar um papel importante na formação e manutenção dos recifes brasileiros. Nos recifes, a riqueza de espécies é baixa em comparação a outros habitats costeiros. *Halimeda* spp., *Dictyota* spp., *Dictyopteris* spp., *Hypnea* spp., *Gracilaria* spp., *Gelidium* spp. e *Sargassum* spp. são alguns dos táxons de algas mais conspícuos, enquanto que espécies de *Caulerpa*, *Udotea* e fanerógamas marinhas ocorrem frequentemente nos fundos de areia não consolidados. Algas bentônicas marinhas são componentes importantes nas comunidades de recifes coralíneos rasos do Atlântico e potencialmente os maiores competidores de corais. Nas últimas duas décadas foram relatados numerosos casos de mudanças de fisionomia nos recifes no mundo, passando de recifes dominados por corais para recifes dominados por algas. Estes eventos coincidem com uma preocupação crescente em relação à degradação de recifes, atribuídos principalmente à eutroficação antropogênica e sobre-pesca. No Brasil, o efeito da eutroficação na dinâmica das comunidades recifais começou a ser verificado, porém ainda faltam informações sobre o enriquecimento de nutrientes nas águas dos recifes de corais. A exploração de algas marinhas,

principalmente *Gracilaria*, também começou no Brasil. A proliferação de macroalgas em alguns recifes brasileiros tem sido associada à redução na herbivoria, causada pela sobre-pesca, ou à eutroficação. Levantamentos rápidos da flora recifal são necessários para estabelecer uma base de dados com informações para o monitoramento e reforço da legislação de proteção aos recifes no Brasil.

**Palavras-chave:** Algas, recifes de coral, diversidade, ecologia, conservação.

## INTRODUCTION

Coral reef biomes have the greatest specific and phyletic biodiversity on the planet. This environment, at first characterized as an animal ecosystem, possesses algal components that may exceed the animal components in diversity and biomass, which are mostly composed of diminutive species (Adey 1998). In some Atlantic reefs, the abundance of macroalgae may exceed the coral coverage; for instance with non-geniculate corallines forming an extensive incrusting layer over the reef borders or turfs and fleshy algae forming a vertical canopy over the corals and other organisms. Because of the great relative contribution of macroalgae to the structure of Brazilian living reef communities, this work aimed to present a major bibliographical revision of their diversity, distribution, and ecological aspects, thus emphasizing the need to continue and intensify the phycological studies of these biomes, which are so sensitive to the environmental degradation caused by human interference.

## REEF ALGAL DIVERSITY

The Brazilian marine benthic macroalgal flora includes around 700 infrageneric taxa (Horta 2000; Nunes 2005), of which nearly 80% are found in the

tropics. Coral reef formations are discontinuously distributed and mainly concentrated in the coast range from the State of Maranhão to northern Espírito Santo (0°40'S to 19°30'S). Rhodophyta is the richest algae division found, and it includes the order Ceramiales, which contains most of the Brazilian species (Figure 1). Chlorophyta mainly comprises Bryopsidales and Cladophorales, while Phaeophyta is chiefly represented by Dictyotales and Ectocarpales (*e.g.* Villaça *et al.* 2006).

Numerous species compose the algal turf – considered itself a taxonomic operational unity (TOU) – which are basically filamentous algae and other delicate specimens. Turfs may be dominated by the geniculated corallines *Jania*, *Amphiroa* and *Halimnion* or contain only filamentous non-coralline algae. Red and brown algae, such as *Anthothamnion*, *Ceramium*, *Digenea*, *Griffithsia*, *Gelidium* and *Sphacelaria*, are common components of algal turfs. Some green algae can also be present, mainly *Enteromorpha*, *Cladophora* and *Bryopsis* (Figueiredo 1997, Villaça & Pitombo 1997, Costa *et al.* 2002). The composition of turfs is similar to what is found in reefs of the Caribbean and Great Barrier, according with Steneck (1988), Adey (1998), and McCook *et al.* (2001). However, this type of TOU is frequently not taxonomically assessed and its specific richness is usually underestimated. In fact, Ceramiaceae together with some delicate

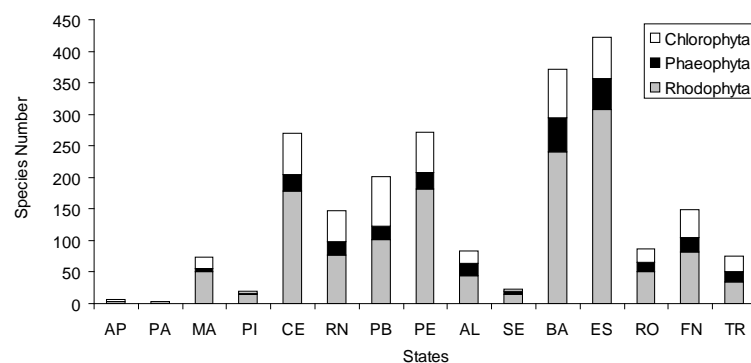


Figure 1. Infrageneric algal diversity of the tropical Brazilian coast according with taxonomic group and location (state or oceanic island). Adapted from Horta *et al.* (2001). Abbreviations of locations: (AP) Amapá, (PA) Pará, (MA) Maranhão, (PI) Piauí, (CE) Ceará, (RN) Rio Grande do Norte, (PB) Paraíba, (PE) Pernambuco, (AL) Alagoas, (SE) Sergipe, (BA) Bahia, (ES) Espírito Santo, (RO) Atol das Rocas, (FN) Fernando de Noronha archipelago, and (TR) Trindade island.

Delesseriaceae and non geniculated Corallinales, are the least studied and least known algae of the Brazilian coral reefs (but see Torres *et al.* 2004, Figueiredo & Steneck 2002). Among the fleshy red algae, the richest and most abundant genus is *Gracilaria* (19 species) of the Brazilian tropical region (Silva *et al.* 1987, Horta 2000, Nunes 2005). From comparing the flora of the Brazilian western Atlantic and of the Caribbean, it can be observed that the Chlorophyta represent a relatively small part to the South Atlantic reef flora (Figure 2).

In subtidal coral reefs even the most conspicuous components of the flora are little known. Although scuba-diving is efficient to investigate heterogeneous and hard substrata, it was rarely used in detailed reef surveys. Considering that constantly submerged areas represent most of the available hard substratum for phytobentic communities, it follows that algal diversity has been sub-estimated. A comparative analysis reveals that many macrophytic species are probably unknown from the Caribbean and adjacent waters, and that the region contains almost twice the number of species of the Southern Atlantic (Norton *et al.* 1996). Littler and Littler (2000) observed that some investigations of certain subtidal reef Chlorophyta of the Caribbean and Western Atlantic yielded more than twice the number of the presently described taxa (*e.g.* Littler & Littler 1990, 1991, 1992). In this group, genera such as *Anadyomene*, *Avrainvillea* and *Udotea* are probably not yet sufficiently known taxonomically and will eventually reveal a greater richness than the presently recorded.

Despite being conspicuous and quite often dominant in the Brazilian coast (Figueiredo 1997, 2000) the non geniculate coralline red algae are poorly known. Figueiredo and Steneck (2002) identified 11 species of corallines in a floristic survey of the reefs of Abrolhos Marine National Park. In a revision of the corallines

of Brazil, Horta (2002) listed all described species and presented an artificial key for the identification of the genera of non-geniculated Corallinales. In earlier studies, Harvey (1847), Dickie (1874, 1875a, b), Piccone (1886), Moebius (1889, 1890), Foslie (1900, 1901), Lemoine (1917) and Taylor (1931, 1960) mentioned genera of non-geniculate Corallinales, but those studies used obsolete techniques and nomenclature.

Little is known about the associations of macroalgae with Brazilian coral reefs in terms of biogeographical patterns. Oliveira Filho (1977) appointed four biogeographical zones in the Brazilian coast. In contrast, Horta *et al.* (2001) presented two main biological zones: a tropical province and warm temperate province, with a transition zone over Espírito Santo state. In later work, Horta (2002) hypothesized that the Brazilian marine flora originated from the Indian Ocean, independently of the processes that brought about the Caribbean flora. These considerations raised issues against about the original hypothesis that the Brazilian flora originated from the Caribbean (Taylor 1955, Oliveira Filho 1977).

Few works employed Feldmann and Cheney indexes to analyze the marine flora of the Brazilian coast. Upon dividing the number of Rhodophyta species of a given region, or the number of Rhodophyta plus Chlorophyta, by the number of Phaeophyta species, it follows that the resulting values are usually lower for regions of higher latitude (Feldmann 1937, Cheney 1977). These indexes should be applied in a large spatial scale (but see Bolton 1986 for South Africa and Garbary 1987 for the North American west coast) and used with caution in small scale studies. Nevertheless, we have determined the Feldmann and Cheney indexes of the states of the Brazilian northern and northeastern coast (Figure 3). The values for the states Maranhão (MA), Ceará (CE), Paraíba (PB), Pernambuco (PE) and

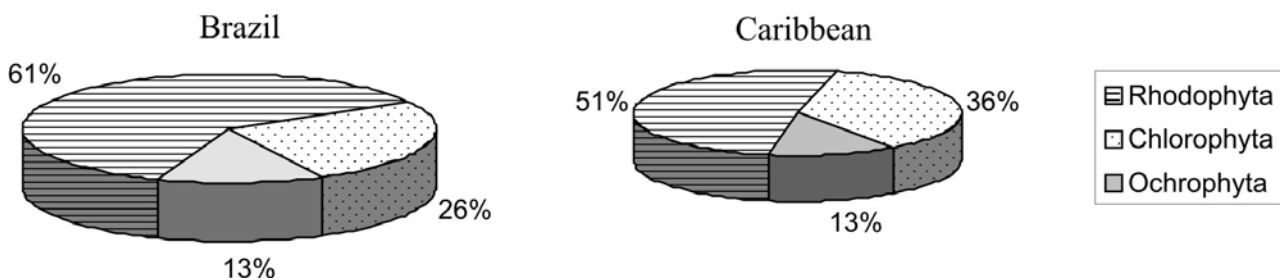


Figure 2. Comparison between the percent composition of algal groups on reefs in the Caribbean and Brazil (according with Littler & Littler 2000 and Horta *et al.* 2001).

Bahia (BA) resulted above four, which is expected for tropical regions (Pinheiro-Joventino *et al.* 1998). The Feldmann index of Rio Grande do Norte (RN) resulted lower than expected, suggesting that the Rhodophyta groups of that region might not be very well studied. Similarly, the Cheney index of Espírito Santo (ES) and Rio Grande do Norte suggest that further studies of Chlorophyta are necessary in those regions. The states of Amapá (AP), Pará (PA), Alagoas (AL) and Sergipe (SE) were found to present low values of Feldmann and Cheney indexes, probably due to the strong influence of fresh water and elevated turbidity resulting of riverine outflows and mangrove areas. In fact, the sediment supply from rivers is known to limit the formation of coral reef along most of the northern coast of Brazil (Leão & Dominguez 2000). Upon working the total number of Brazilian taxons recorded, these indexes resulted similar to those of the tropical Caribbean region (based on data from Littler & Littler, 2000 and Horta *et al.* 2001) (Figure 4).

A biogeographical analysis, therefore, can only be made after a more complete inventory of the algae of Brazilian reef systems is built. Studies about macroalgal dispersion are also necessary in order to understand biogeographical patterns (Norton 1992), especially of widely distributed and invasive species (Deysner & Norton 1982). For example, 'natural' dispersal over large distances can be due to the ability of some algae, such as *Sargassum* spp., to float. The *Sargassum* transports a significant variety of algae along the

Brazilian current (Oliveira *et al.* 1979). Nevertheless, nowadays, humans are the world's greatest evolutionary force (Palumbi 2001), potentializing dispersal over long distances through ballast water discharges and fouling (Hoek 1987, Carlton & Geller 1993) or by introducing species for mariculture (Russell 1982, 1987). Other kinds of human impacts on the biosphere can also disturb the dispersal capability of algal spores, as well as affect dispersal of coral planula (Norton 1992, Sammarco 1996). These factors, taken together with global warming, can change selective pressures, altering the actual biogeographical pattern and may cause economical impacts to humans (Beardall *et al.* 1998). Considering these flaws, knowledge about the benthic macroalgal diversity becomes necessary for Brazilian coral reef conservation and their sustainable exploitation is unfeasible and insufficient for supporting effective management programs.

## ECOLOGY OF REEF ALGAE COMMUNITIES

Macroalgae are known to be among the most common organisms on many Brazilian living reefs (Figueiredo 2000). In northern regions, the reefs are mainly composed of crustose coralline algae, vermetids, and corals (Kempf 1968, Castro & Pires 2001). Fleishy and articulated calcareous macroalgae may also cover extensive areas and form high standing crops on the reefs. On the coastal windward reefs of Itamaracá island of Pernambuco state, the alga *Gracilaria* spp.,

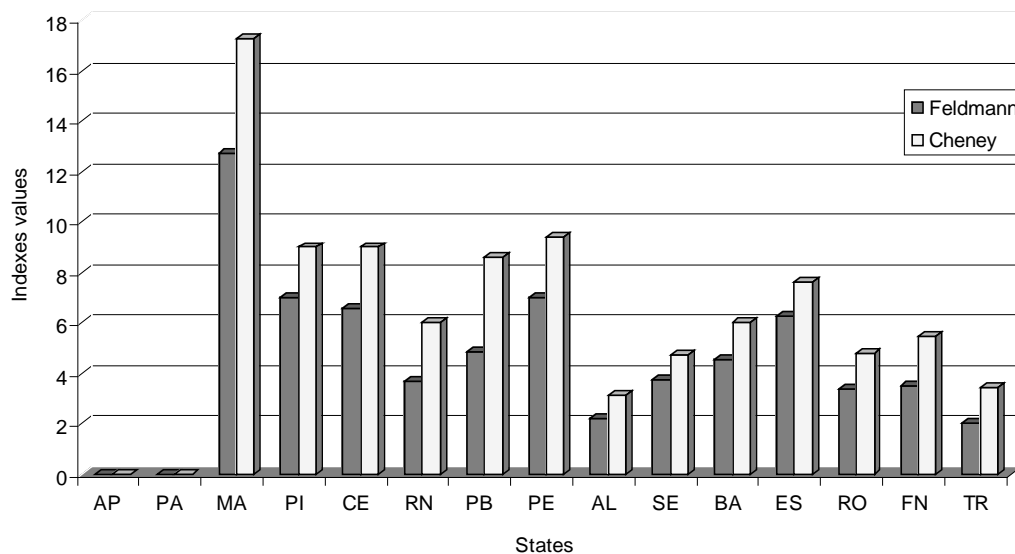


Figure 3. Feldmann and Cheney indexes of the northern to northeastern states of Brazil and oceanic islands. Abbreviations: (AP) Amapá, (PA) Pará, (MA) Maranhão, (PI) Piauí, (CE) Ceará, (RN) Rio Grande do Norte, (PB) Paraíba, (PE) Pernambuco, (AL) Alagoas, (SE) Sergipe, (BA) Bahia, (ES) Espírito Santo, (RO) Atol das Rocas, (FN) Fernando de Noronha archipelago and (TR) Trindade island.



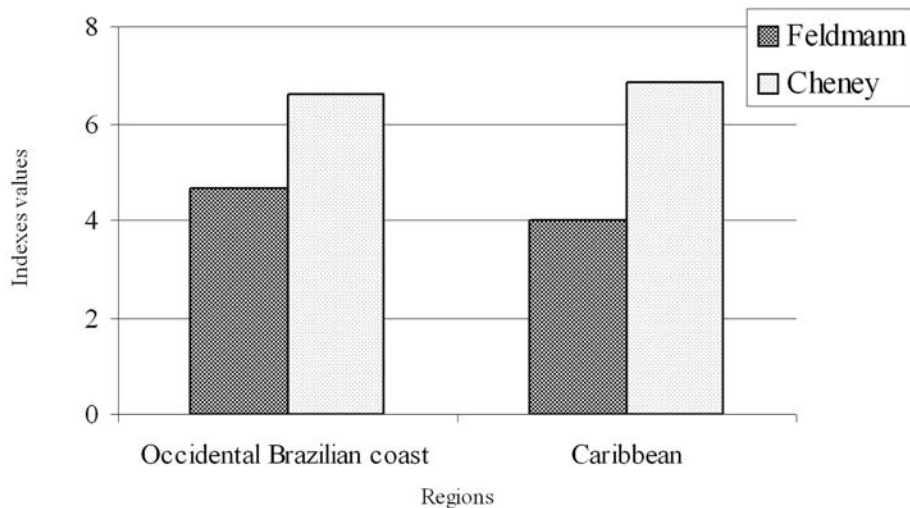


Figure 4. Feldmann and Cheney indexes of reef flora in Brazil and the Caribbean (based on Littler & Littler 2000 and Horta *et al.* 2001).

together with the red macroalgae *Hypnea musciformis*, *H. cervicornis*, and *Solieria filiformis*, and the green algae *Caulerpa* spp. locally achieve elevated biomass of up to 1,020g of fresh weight/ m<sup>2</sup> in the summer (Silva *et al.* 1987). At the Fernando de Noronha Archipelago, located at 345km from Natal in Rio Grande do Norte state, the brown alga *Dictyota mertensii* and the red alga *Laurencia papillosa* are dominant over shallow fringing reefs, along with the calcareous green alga *Halimeda tuna* and the red alga *Amphiroa fragilissima* (Pereira *et al.* 1996). In deeper areas, some brown algae species, mainly *Sargassum*, *Dictyota*, *Dictyopteris* and *Styopodium*, become predominant (Eston *et al.* 1986). Over the southern reefs of Porto Seguro in Bahia state, algal turfs are always predominant, covering from 20 to 40% of the reef habitats. Green and brown fleshy algae and articulated calcareous red algae are also found (10 to 25%) on the reef flats coastal and offshore sites in Bahia along with *Caulerpa*, *Dictyosphaeria*, *Dictyota*, *Padina*, *Sargassum*, *Gelidiella*, and *Amphiroa* as the most abundant taxa (Costa *et al.* 2002). Small turf-forming algae are also abundant in the Abrolhos Marine National Park, covering from 25 to 80% of hard substratum of coastal and offshore reefs. Over most of the remaining coastal reefs of the Abrolhos Bank, large fleshy macroalgae are predominant (between 50 and 90% of coverage), mainly the brown algae *Dictyota*, *Dictyopteris*, *Lobophora*, *Padina*, *Spatoglossum*, *Styopodium*, and *Sargassum* (Amado Filho *et al.* 1997, Figueiredo 1997, Villaça & Pitombo 1997, Figueiredo 2006).

A large number of macroalgae species of Caulerpaceae, Udoteaceae and Bryopsidaceae coexist with the seagrasses *Halodule wrightii* and *Halophila decipiens* on the biodetritic soft bottoms around or over the reefs of northern (Silva *et al.* 1987, Testa 1997, Pereira & Accioly 1998) and southern Brazil (Creed & Amado 1999, Figueiredo 2006). Creeping rhizomes allow those episamic macrophytes to thrive amongst the reefs and their leaves serve as hosts to many epiphytes. The seagrass *Udotea flabellum* was found to be the most available hard substratum in the reefs of Abrolhos (Paula *et al.* 2003), though relatively less important than is *Halimeda opuntia* in the reefs of northern Serrambi (Pereira & Accioly 1998). On the soft bottoms near to reefs, free living coralline algae also known as rhodoliths and maerls, like *Sporolithon*, *Mesophyllum* and *Lithothamnion*, are also found in association with seagrass meadows or forming extensive deposits (Testa 1997, Figueiredo & Steneck 2002, Paula *et al.* 2003, Figueiredo *et al.* 2006). Although carbonate sediment deposits are commonly found along both the northern and north-eastern continental shelf of Brazil (Kempf 1980), their origin and how they are transported across the reef areas are poorly known (but see Testa 1997, Leão & Dominguez 2000, Leão *et al.* 2003).

Crustose coralline algae, especially *Lithophyllum*, are commonly found in association with vermetids on the inner shelf of the reefs of northern Brazil (Testa 1997). This contrasts with the coralline-algal frameworks of Atol das Rocas, which are dominated by *Porolithon* alone (Gherardi & Bosence 2001, Villas Bôas *et al.* 2005). In

the Abrolhos Archipelago, *Porolithon pachydermum* (Foslie) Foslie and *Lithophyllum congestum* (Foslie) Foslie are the coralline crusts of the shallow zones, where they cover as much as 80% of the fringing reefs and 50% of the columnar reefs. Sometimes they are barely visible, for growing under a thin sediment layer. Over the remaining areas of the Abrolhos Bank coralline crusts are less common, usually presenting < 30% coverage of coastal reefs (Figueiredo 1997, 2000, 2006, Figueiredo & Steneck 2002). The species found in Abrolhos, together with *Neogoniolithon strictum* (Foslie) Setchell & Manson, are the primary reef builders in the Caribbean, dominating the high energy algal ridges (Adey 1975, Adey & Vassar 1975, Steneck *et al.* 1997). Coralline crusts living in cryptic and deeper reef zones require more careful investigation because the species composition may change from thick to thin crusts in low light environments (Steneck 1986, Dethier *et al.* 1991) and we do not have much information on these crusts.

The distribution and abundance of benthic algae on most reefs of Brazil is poorly known because community level studies are scarce. In reef areas of the northern coast, most surveys were done on shallow and emergent reefs, so we know little about how communities change with depth. About the reefs of the offshore zone of the northern coast, it is known that coralline crusts are the main component of windward reefs at Atol das Rocas, increasing in abundance from 45% on the reef flats to 70% on the reef walls (Gherardi & Bosence 2001). Crustose corallines are occasionally present in the intertidal zone and tend to occupy more space in deep zones (up to 50-70%) under a dense macroalgae canopy over vermetid reef platforms in the Fernando de Noronha Archipelago (Eston *et al.* 1986). The pattern in the southern reefs of Porto Seguro is of coralline crusts and fleshy macroalgae covering 50-60% of the reef flats and decreasing to 30% over the reef walls of coastal and offshore areas (Costa *et al.* 2002). On the Abrolhos Bank, the fleshy macroalgae mainly grow over reef walls forming dense stands, but coralline crusts have a more variable habitat distribution, ranging 5-40% on the reef flats, 30-80% on the reef crests and 10-50% on the reef walls. The spatial variability of these patterns depends on the abundance of turf algae and herbivory pressure (Figueiredo 1997, 2000, Figueiredo & Steneck 2002).

Alternating dominance between corals and algae in the reef communities has been associated with either reduced grazing or nutrient enrichment, or a combination of both factors (Lapointe *et al.* 1997). In many Caribbean reefs, a substantial increase on the abundance of macroalgae was observed following urchin mass mortality (Williams & Polunin 2001) and hurricanes (Rogers *et al.* 1997). In the Abrolhos reefs, sea urchins form low density populations with little impact over the algal community, in contrast with the more abundant herbivorous scarid and acanthurid fishes, which can achieve elevated numbers in areas where fishing is not allowed (Villaça & Pitombo 1997, Figueiredo 1997, 2006, Figueiredo & Steneck 2002, Ferreira & Gonçalves 1999). Filamentous algal turfs grow fast and thus compensate for thallus loss by grazing and have advantage over the large macroalgae of grazed reefs (Steneck 1988, Steneck & Dethier 1994). Crustose corallines are also common on shallow productive reefs (Villas Boas *et al.* 2005, Tâmega & Figueiredo 2007). In reefs in which fishing is not allowed, herbivore fishes help remove the algal fouling from the surface of coralline algae. However, the high grazing pressure of scarid fish can limit the abundance of coralline algae and their growth rates (Figueiredo 1997). In contrast, on the Abrolhos Bank fleshy macroalgae and articulated calcareous algae are dominant on coastal reefs. There is no consensus as to whether this is a result of nutrient enrichment due to terrestrial runoff (Coutinho *et al.* 1993, Leão *et al.* 1994, Costa *et al.* 2002) or lowered fish herbivory because of overfishing (Ferreira & Gonçalves 1999). In other reefs, calcareous algae have been found to benefit from nutrient-enriched waters if the grazers consumed the more palatable fleshy algae (Thacker *et al.* 2001, Smith *et al.* 2001).

In highly depositional environments near the shore, the competition between different algal groups was suggested to explain the negative relationship found between the abundance of coralline crusts and algal turfs (Figueiredo & Steneck 2002). Sediments trapped within the turfs may affect the recruitment of crusts by preempting and reduce photosynthesis by shading as well as restricting the gas exchange (Kendrick 1991, Steneck 1997, Fabricious & De'ath 2001). In contrast, the competition between macroalgae and corals is less intense, since corals are not very abundant on the reefs of Brazil (Pitombo *et al.* 1988, Villaça & Pitombo 1997, Castro & Pires 1999). Algae are able to quickly

occupy the newly available substrate when corals die due to environmental stress and diseases (McClanahan *et al.* 2001, Lirman 2001). However, it is difficult to assess whether algae are actively competing with corals or simply occupying the space left by their death (Miller & Hay 1996, McCook 2001, McCook *et al.* 2001). In addition, there is a lack of background data and reports on when bleaching events started in Brazil (Castro & Pires 1999, Creed, Figueiredo, Castro & Pires unpublished data). Therefore, studying the relationships between algal symbionts (zooxanthellae) and the mortality and survival of corals after bleaching events (Spencer-Davies 1992) will help understand the competition with macroalgae.

Despite their importance in structuring reef communities, the plant and animal interactions between crustose corallines, macroalgae and invertebrates have not been investigated in Brazilian reefs. Because of their extensive living coverage on reefs, the coralline crusts may be one of the major community structuring reef organisms. Their cell walls are heavily impregnated with calcium carbonate in the form of calcite (Cabioch & Giraud 1986), and provide structural resistance to erosion offering refuge and nursery sites for small invertebrates (Pitlick & Paul 1997). Some of these red algae also produce chemical cues known to induce settlement and metamorphosis of larvae of tubeworms, abalone, chitons, asteroids, urchins and soft and scleratinian corals (Morse 1992). However, fouling organisms can be deterred by some corallines which are able to shed their superficial layers, mainly in low light environments, such as cryptic habitats, deep reefs and under algal canopies (Steneck 1997, Littler & Littler 1999). Only a detailed knowledge of the taxonomy of coralline crusts would permit the recognition of coralline-coral and coralline-other plant or animal interactions (Figueiredo *et al.* 1996, Morcom & Woelkerling 2000).

## REEF ALGAE CONSERVATION

Regarding conservation, the macroalgae are not a major concern but are considered a major nuisance on reefs elsewhere from the tropics. Nowadays, shifts from coral to macroalgae domination in the communities are usually associated with reef degradation (McCook *et al.* 1997). Although macroalgae are not threatened and endemic species are unknown, there are common

species known to the majority of protected reefs (Table I) within the Brazilian National Conservation System (Pedrini 1990). There are numerous conservation units in Bahia State, where coral reef formations are commonly found, including a national park, an environmental protected area and a fishing reserve. The most extensive protected area of reef systems is found in the coasts of Pernambuco and Alagoas States, although the local marine flora is only known from isolated studies of a few localities. The floras of the Marine National Parks of Abrolhos and Fernando de Noronha present the highest species richness, but most probably as a result of greater sampling efforts.

Coral reef systems all over the world experienced an increase in disturbances related to coastal erosion, hurricanes, nutrient enrichment, pollution, diseases, overfishing and changes in the water temperature. These factors taken together or separately change the structure of communities in association with reefs (McClanahan 2000). Eutrophication of inshore reefs near urbanized areas has resulted in macroalgae proliferation and a decrease in species diversity (Littler *et al.* 1992). Macroalgae dominated communities may be favored by nutrient enrichment, but also by overfishing (McClanahan *et al.* 1999, Tussenbroek & Vides 2000, Williams & Polunin 2001, Littler *et al.* 2006). One probable consequence of overfished reefs is that macroalgae protected by their calcified thalli or deterrent secondary metabolites (Hay 1997, Pitlick & Paul 1997) may eventually be substituted by more palatable fleshy algae. Such macroalgal beds are not the preferred habitat of these scraping and excavating herbivorous fishes and so a return to the former state would be difficult (McClanahan *et al.* 1999). Conversely, phase shifts from coralline/coral to turf-algal domination have been reported on intensively grazed reefs after broad scale epidemic diseases, such as the coralline lethal orange disease (Littler & Littler 1997). In fact, macroalgae are not necessarily more successful competitors than corals in eutrophic environments (McCook 2001) and not always kill corals by overgrowing them (Lirman 2001), but are opportunistic organisms that quickly take over spaces opened by the processes that cause reef degradation (McCook *et al.* 1997, McClanahan *et al.* 1999).

Preservation of species diversity and exploitation of macroalgae beds are regulated by Brazilian legislation in order to provide sustainable use (Constitution,



Environmental Crimes Law and Environmental Agency Regulations). Among Brazilian reef communities, species that present potential use for colloid production are *Gracilaria* and *Hypnea* spp. (Silva *et al.* 1987). The exploitation process involves the local community who monthly remove around 80 tons of dry material (Oliveira & Miranda 1998), an activity that threatens diversity and maintenance of macroalgal beds of coastal reefs. Rhodolith and maerl beds formed by free living non-geniculate corallines are another widely distributed resource often associated with Brazilian reefs. These calcareous algae have potential uses as fertilizers and lime to correct soil pH, though their extraction may cause severe impacts on other living resources (Foster 2001).

Table I. Richness of reef algae species in the Brazilian National Conservation System

Conservation Units (State)	Number of species	References
Fernando de Noronha National Park (PE)	122	1, 2, 3
Abrolhos Marine National Park (BA)	138	4, 5, 6, 7, 8, 9, 10
Rocas Marine Reserve (RN)	93	11
Corais Environmental Protected Area (PE, AL)	58	12, 13, 14
Baleia Environmental Protected Area (BA)	81	10
Recife de Fora Environmental Protected Area (BA)	51	15
Rio Mamanguape Environmental Protected Area (AL)	58	16
Corumbau Fishing Reserve (BA)	93	10

(1) Eston *et al.* 1986, (2) Pereira *et al.* 1996, (3) Pedrini *et al.* 1992, (4) Joly *et al.* 1969, (5) Amado *et al.* 1997, (6) Creed & Amado 1997, (7) Figueiredo 1997, (8) Villaça & Pitombo 1997, (9) Figueiredo & Steneck 2002, (10) Figueiredo 2006, (11) Pedrini 1990, (12) Pereira & Accioly 1998, (13) Muñoz & Pereira 1997, (14) Muñoz & Pereira 1998, (15) Costa *et al.* 2002, (16) Kanagawa, *pers. comm.*

The conservation of biodiversity is a major goal of the Brazilian government, which has implemented the National Biodiversity Program (Pronabio) to survey the national biodiversity, including coastal and marine environments, in order to indicate priority areas for conservation. Because of their potential economical uses macroalgae have been indicated as one of the main living resources that should be preserved. Therefore, we need to better understand their role in maintaining

diversity and functions of other living organisms in order to protect and support the sustainable use of reef systems. However, the contribution of calcified macroalgae to the reef framework, which enhances biodiversity (Hay 1997, Paul 1997, Pitlik & Paul 1997) and propels biogeochemical cycles, is unknown in Brazil. Although structurally strong, their growth and calcification are negatively affected by high concentrations of certain nutrients, especially phosphate (Maudsley 1990). Heavy metal is another threat, mainly to brown algal species along coastal reef areas in the south of Bahia State (Amado Filho *et al.* 1997). Considering the importance of coralline algae as reef builders, the particularly harmful pollution of coastal waters should be monitored to sustain healthy reefs.

## CONCLUSIONS

Coral reef habitats are characterized by an elevated spatial heterogeneity produced by extensive calcium carbonate structures with a superabundance of surfaces and internal or cryptic spaces (Adey 1998). Therefore, species diversity and density are expected to be the highest over all of any set of ecosystems. However, the diversity of the Brazilian reef flora is relatively low, indicating that either our reefs are under-studied or exposed to exceedingly intense disturbances, such as fish herbivory (Norton *et al.* 1996). Since taxonomic surveys may be not sufficient to detect disturbances, a functional group approach may be a good alternative to quickly assess seasonal changes or shifts among macroalgae groups reflecting selective adaptation to disturbance (Steneck & Dethier 1994). The importance of a more modern approach to better understanding of the diversity of macroalgae is justified by the important ecological role of some groups, such as calcareous algae (Steneck & Testa 1997), to this environment. Some Brazilian reefs are chiefly composed by crustose coralline algae, which, along with the stony corals, form relatively large geological structures (Kikuchi & Leão 1997), but calcareous green algae can also be one of the major components of the sediments around reefs (Leão 1982, Leão & Dominguez 2000, Testa 1997, Leão & Kikuchi 2001, Leão *et al.* 2003).

Habitat fragmentation and loss of functional diversity in consequence of human activities are altering the resilience, or the capacity of coral reefs to confront future disturbances (Nyström *et al.* 2000). In summary,



rapid biodiversity assessments are needed to identify regional priorities and provide baseline information to long-term reef monitoring programs in order to successfully conserve the reef communities of Brazil.

## REFERENCES

- ADEY, W.H. 1975. The algal ridges and coral reefs of St. Croix: their structure and Holocene development. *Atoll Research Bulletin*, 187: 1-67.
- ADEY, W.H. 1998. Coral reefs: algal structured and mediated ecosystems in shallow, turbulent, alkaline waters. *Journal of Phycology*, 34: 393-406.
- ADEY, W.H. & VASSAR, J.M. 1975. Colonization, succession and growth rates of tropical crustose coralline algae (Rhodophyta, Cryptonemiales). *Phycologia*, 14: 55-69.
- AMADO, G.M.; ANDRADE, L.R.; REIS, R.P.; BASTOS, W. & PFEIFFER, W.C. 1997. Heavy metal concentrations in a seaweed species from the Abrolhos reef region, Brazil. In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 1843-1846.
- BEARDELL, J.; BEER, S. & RAVEN, J.A. 1998. Biodiversity of marine plants in an era of climate change: some predictions based on physiological performance. *Botanica Marina*, 41: 113-123.
- BOLTON, J.J. 1986. Marine phytogeography of the Benguela upwelling region on the west coast of Southern Africa: a temperature dependent approach. *Botanica Marina*, 29: 251-256.
- BRAGA, M.R.A. & PEREIRA, S.M.B. 1992. Algas marinhas bentônicas do Arquipélago de Fernando de Noronha, Brasil. *Boletim de Botânica da Universidade de São Paulo*, 13: 93-101.
- CABIOCH, J. & GIRAUD, G. 1986. Structural aspects of biomineralization in the coralline algae (calcified Rhodophyceae). Pp 141-156. In: B.S.C. Leadbeater & R. Riding, (eds.), Biomineralization in lower plants and animals. The Systematic Association, Special Volume nº 30. Clarendon Press, Oxford.
- CARLTON, J.T. & GELLER, J.B. 1993. Ecological roulette, the global transport of nonindigenous marine organisms. *Science*, 261: 78-82.
- CASTRO, C. B. & PIRES, D.O. 1999. A bleaching event on a Brazilian coral reef. *Revista brasileira de Oceanografia*, 47: 87-90.
- CASTRO, C. B. & PIRES, D.O. 2001. Brazilian coral reefs: what we already know and what is still missing. *Bulletin of Marine Science*, 69 (2): 357-371.
- CHENEY, D.F. 1977. R+C/P, a new improved ratio for comparing seaweed floras. *Journal of Phycology*, 13(supl.): 12.
- COSTA JR., O. S.; ATTRILL, M. J.; PEDRINI, A.G. & PAULA, J.C. de. 2002. Benthic macroalgal distribution in coastal and offshore reefs at Porto Seguro Bay, Brazilian Discovery Coast. In: Proceedings of the 9<sup>th</sup> International Coral Reef Symposium, Bali. pp: 499-508.
- COUTINHO, R.; VILLAÇA, R.C.; GUIMARAENS, M.A.; APOLINÁRIO, M. & MURICY, G. 1993. Influência antrópica nos ecossistemas corálinos da região de Abrolhos, Bahia, Brasil. *Acta Biologica Leopoldensia*, 15: 133-144.
- CREED, J. C. & AMADO FILHO, G. M. 1999. Disturbance and recovery of the macroflora of a seagrass (*Halodule wrightii* Ascherson) meadow in the Abrolhos Marine National Park, Brazil: an experimental evaluation of anchor damage. *Journal of Experimental Marine Biology and Ecology*, 235: 285-306.
- DETHIER, M.N.; PAUL, K.M. & WOODBURY, M. M. 1991. Distribution and thickness patterns in subtidal encrusting algae from Washington. *Botanica Marina*, 34: 201-210.
- DEYSHER, L. & NORTON, T. A. 1982. Dispersal and colonization in *Sargassum muticum*. *Journal of Experimental Marine Biology and Ecology*, 56: 179-195.
- DICKIE, G. 1874. Enumeration of algae collected at Fernando de Noronha. *Journal of the Linnean Society of London (Botany)*, 14: 363-365.
- DICKIE, G. 1875a. Enumeration of algae collected at St. Paul's rocks by H.N. Mosely, M.A. naturalist, to H.M.S. "Challenger". *Journal of the Linnean Society of London (Botany)*, 14: 355-359.
- DICKIE, G. 1875b. Enumeration of algae collected from Bahia, collected by H.N. Mosely, M.A. naturalist, to H.M.S. "Challenger". *Journal of the Linnean Society of London (Botany)*, 14: 377.
- ESTON, V.R.; MIGOTTO, A.E.; OLIVEIRA FILHO, E.C.; RODRIGUES, S.A. & FREITAS, J.C. 1986. Vertical distribution of benthic marine organisms on rocky coasts of the Fernando de Noronha Archipelago (Brazil). *Boletim do Instituto Oceanográfico de São Paulo*, 34: 37-53.
- FABRICIUS, K. & DE' ATH, G. 2001. Environmental factors associated with the spatial distribution of crustose coralline algae on the Great Barrier Reef. *Coral Reefs*, 19: 303-309.
- FELDMANN, J. 1937. Recherches sur la végétation marine de la Méditerranée. La cotes des Alpes. *Revue Algologique*, 10: 1-33.
- FERREIRA, C.E.L. & GONÇALVES, J.E.A. 1999. The unique Abrolhos reef formation (Brazil): need for specific management strategies. *Coral Reefs*, 18: 352.
- FIGUEIREDO, M.A.O. 1997. Colonization and growth of crustose coralline algae in Abrolhos, Brazil. In: Proceeding of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 689-694.
- FIGUEIREDO, M.A.O. 2000. Recifes de coral ou recifes de algas? *Ciência Hoje*, 28(166): 74-76.
- FIGUEIREDO, M.A.O. 2006. Diversity of macrophytes in the Abrolhos Bank, Brazil. In: G.F. Dutra; G.R. Allen, T. Werner & S.A. McKenna, (eds.), A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. *RAP Bulletin of Biological Assessment*, 38: 67-74.
- FIGUEIREDO, M.A.O.; MENEZES, K.S.; PAIVA, E.M.C.; PAIVA, P.C. & VENTURA, C.R.R. 2007.

- Evaluación experimental de rodolitos como sustratos vivos para la infauna en el Banco de Abrolhos, Brasil. *Ciencias Marinas*, 33: 427-440.
- FIGUEIREDO, M.A.O. & STENECK, R.S. 2002. Floristic and ecological studies of crustose coralline algae on Brazil's Abrolhos reefs. *In: Proceedings of the 9<sup>th</sup> International Coral Reef Symposium*, Bali. pp: 493-498.
- FIGUEIREDO, M.A.O.; KAIN (JONES), J.M. & NORTON, T.A. 1996. Biotic interactions in the colonization of crustose coralline algae by epiphytes. *Journal of Experimental Marine Biology and Ecology*, 199: 303-318.
- FOSLIE, M. 1900. Revised systematical survey of the Melobesieae. *Kongelige Norske Videnskabernes Selskabs Skrifter*, 5: 1-22.
- FOSLIE, M. 1901. New Melobesieae. *Kongelige Norske Videnskabernes Selskabs Skrifter*, 6: 2-24.
- FOSTER, M.S. 2001. Rhodoliths: between rocks and soft places. *Journal of Phycology*, 37: 659-667.
- GARBARY, D. 1987. A critique of traditional approaches to seaweed distribution in light of the development of vicariance biogeography. *Helgoländer Meeresunters*, 41: 235-244.
- GHERARDI, D.F.M. & BOSENCE, D.W.J. 2001. Composition and community structure of the coralline algal reefs from Atol das Rocas, South Atlantic, Brazil. *Coral Reefs*, 19: 205-220.
- HARVEY, W.H. 1847. Corallineae. *Phycologia britannica*, 1: 1-124.
- HAY, M.E. 1997. Calcified seaweeds on coral reefs: complex defenses, trophic relationships, and value as habitats. *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 713-718.
- HOEK, C. VAN DEN. 1987. The possible significance of long-range dispersal for the biogeography of seaweeds. *Helgoländer Meeresunters*, 41: 261-272.
- HORTA, P.A. 2000. *Macroalgas do infralitoral do sul do Brasil: taxonomia e biogeografia*. Tese de Doutorado, Universidade de São Paulo, São Paulo. Brasil. 301p.
- HORTA, P.A. 2002. Bases para a identificação das coralináceas não articuladas do litoral brasileiro – uma síntese do conhecimento. *Biotemas*, 15 (1): 7-44.
- HORTA, P.A.; AMANCIO, E.; COIMBRA, C.S. & OLIVEIRA E.C. 2001. Considerações sobre a distribuição e origem da flora de macroalgas marinhas brasileiras. *Hoehnea*, 28: 243-265.
- KEMPF, M. 1980. Perspectiva de exploração econômica dos fundos de algas calcárias da plataforma continental do nordeste do Brasil. *Trabalhos Oceanográficos da Universidade Federal de Pernambuco*, 15: 139-164.
- KEMPF, M. & LABOREL, J. 1968. Formations de vermetes et d'algues calcaires sur les cotes du Brésil. *Recueil des Travaux de la Station Marine d'Endoume*, 43: 9-23.
- KENDRICK, G.A. 1991. Recruitment of coralline crusts and filamentous turf algae in the Galapagos archipelago: effect of simulated scour, erosion and accretion. *Journal of Experimental Marine Biology and Ecology*, 147: 47-63.
- KIKUCHI, R.K.P. & LEÃO, Z.M.A.N. 1997. Rocas (southwestern equatorial Atlantic, Brazil): an atoll built primarily by coralline algae. *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 731-736.
- LAPOINTE, B.E.; LITTLER, M.M. & LITTLER, D.S. 1997. Macroalgal overgrowth of fringing coral reefs at Discovery Bay, Jamaica: bottom-up versus top-down control. *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 927-932.
- LEÃO, Z.M.A.N. 1982. *Morphology, geology and developmental history of the southernmost coral reefs of western Atlantic, Abrolhos Bank, Brazil*. PhD. Thesis, University of Miami, Coral Gables, USA. 218p.
- LEÃO, Z.M.A.N. & DOMINGUEZ, J.M.L. 2000. Tropical Coast of Brazil. *Marine Pollution Bulletin*, 41: 112-122.
- LEÃO, Z.M.A.N. & KIKUCHI, R.K.P. 2001. The Abrolhos reefs of Brazil. Coastal Marine Ecosystems of Latin America. Pp 83-96. *In: U. Seelinger & B. Kjerfve*, (eds.), Springer-Verlag: Berlin.
- LEÃO, Z.M.A.N.; KIKUCHI, R.K.P.; TESTA, V. 2003. Corals and Coral Reefs of Brazil. Pp 9-52. *In: J. Cortés*, (ed.), Latin America Coral Reefs. Elsevier Science: Amsterdam.
- LEÃO, Z.M.A.N.; TELLES, M.D.; SFORZA, R.; BULHÕES, H.A & KIKUCHI, R.K.P. 1994. Impact of tourism development on the coral reefs of the Abrolhos area, Brazil. *In: Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health, Hazards and History*, Miami, pp. 254-260.
- LEMOINE, M. 1917. Les Mélobésiées de Antilles danoises recoltées por M. Børgesen. *Bulletin du Muséum National d'Historie Naturelle, (Paris)* 2: 1-4.
- LIRMAN, D. 2001. Competition between macroalgae and corals: effects of herbivore exclusion and increased algal biomass on coral survivorship and growth. *Coral Reefs*, 19: 392-418.
- LITTLER, D.S. & LITTLER, M.M. 1990. Systematics of *Udotea* species (Bryopsidales, Chlorophyta) in the tropical western Atlantic. *Phycologia*, 29: 206-252.
- LITTLER, D.S. & LITTLER, M.M. 1991. Systematics of *Anadyomene* species (Anadyomeneaceae, Chlorophyta) in the tropical western Atlantic. *Journal of Phycology*, 27: 101-118.
- LITTLER, D.S. & LITTLER, M.M. 1992. Systematics of *Avrainvillea* species (Bryopsidales, Chlorophyta) in the tropical western Atlantic. *Phycologia*, 31: 375-418.
- LITTLER, M.M. & LITTLER, D.S. 1997. Disease-induced mass mortality of crustose coralline algae on coral reefs provides rationale for the conservation of herbivorous fish stocks. *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 719-724.
- LITTLER, M.M. & LITTLER, D.S. 1999. Epithallus sloughing: a self-cleaning mechanism for coralline algae. *Coral Reefs*, 18: 204.
- LITTLER, M.M. & LITTLER, D.S. 2000. Caribbean Reef Plants. Off Shore Graphics, Inc. Washington, D.C. 542p.

- LITTLER, M.M.; LITTLER, D.S. & LAPOINTE, B.E. 1992. Modification of tropical reef community structure due to cultural eutrophication: the southwest coast of Martinique. *In: Proceedings of the 7<sup>th</sup> International Coral Reef Symposium*, Guam. pp: 335-343.
- LITTLER, M.M.; LITTLER, D.S. & BROOKS, B.L. 2006. Harmful algae on tropical coral reefs: Bottom-up eutrophication and top-down herbivory. *Harmful Algae*, 5: 565-585.
- MAUDSLEY, B. 1990. Defenders of the reef. *New Scientist*, 1714: 51-56.
- MCCLANAHAN, T.R. 2000. Bleaching damage and recovery potential of Maldivian coral reefs. *Marine Pollution Bulletin*, 40(7): 587-597.
- MCCLANAHAN, T.R.; AROSON, R.B.; PRECHT, W.F. & MUTHIGA, N.A. 1999. Fleishy algae dominate remote coral reefs of Belize. *Coral Reefs*, 18: 61-62.
- MCCLANAHAN, T.R.; MUTHIGA, N.A. & MANGI, S. 2001. Coral and algal changes after the 1998 coral bleaching: interaction with reef management and herbivores on Kenyan reefs. *Coral Reefs*, 19: 380-391.
- MCCOOK, L.J. 2001. Competition between corals and algal turfs along a gradient of terrestrial influence in the nearshore central Great Barrier. *Coral Reefs*, 19: 419-329.
- MCCOOK, L.J.; JOMPA, J. & DIAZ-PULIDO, G. 2001. Competition between corals and algae on coral reefs: a review of evidence and mechanisms. *Coral Reefs*, 19: 400-425.
- MCCOOK, L.J.; PRICE, I.R. & KLUMPP, D.W.L. 1997. Macroalgae on the GBR: causes or consequences, indicators or models of reef degradation? *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 1851-1856.
- MENEZES, COSTA-PAIVA2, PAIVA & VENTURA. 2007. Experimental evaluation of rhodoliths as living substrata for infauna at the Abrolhos Bank, Brazil *Figueiredo; Ciencias Marinas* (2007), 33(4): 427-440
- MILLER, M.W. & HAY, M.E. 1996. Coral-seaweed-grazer-nutrient interactions on temperate reefs. *Ecological Monographs*, 66(3): 323-344.
- MOEBIUS, M. 1889. Bearbeitung der von H. Shenk in Brasilien gesammelten Algen. *Hedwigia*, 28: 309-347.
- MOEBIUS, M. 1890. Algae brasiliensis a cl. Dr. Glaziou collectae. *Notarisia*, 5: 1065-1090.
- MORCOM, N.F. & WOELKERLING, W.J. 2000. A critical interpretation of coralline-coralline (Corallinales, Rhodophyta) and coralline-other plant interactions. *Cryptogamie Algologie*, 21(1): 1-31.
- MORSE, A.N.C. 1992. Role of algae in recruitment of invertebrate larvae. *In: D.M. John, S.J. Hawkins & J.H. Price* (eds.). *Plant-animal interactions in the marine benthos*. Clarendon Press, Oxford, The Systematics Association, 46: 385-403.
- MUÑOZ, A.O.M. & PEREIRA, S.M.B. 1997. Caracterização quali-quantitativa das comunidades de macroalgas nas formações recifais da Praia do Cupe - Pernambuco (Brasil). *Trabalhos Oceanográficos da Universidade Federal de Pernambuco*, 25: 93-109.
- MUÑOZ, A.O.M. & PEREIRA, S.M.B. 1998. Estrutura de comunidades de macroalgas em formações recifais do Estado de Pernambuco, Brasil. *Anais do IV Congresso Latino-Americano, II Reunião Ibero-Americana, VII Reunião Brasileira de Ficologia*, Caxambu. pp: 287-297.
- NORTON, T.A. 1992. Dispersal by macroalgae. *British Phycological Society*, 27: 293-301.
- NORTON, T.A.; MELKONIAN, M. & ANDERSEN, R.A. 1996. Algal biodiversity. *Phycologia*, 35(4): 308-326.
- NUNES, J.M.C. 2005. *Rodofíceas marinhas bentônicas do estado da Bahia, Brasil*. Tese de Doutorado, Universidade de São Paulo, São Paulo, Brasil. 271 p.
- NYSTRÖM, M.; FOLK, C. & MOBERG, F. 2000. Coral reef disturbance and resilience in human-dominated environment. *Tree*, 15(10): 413-417.
- OLIVEIRA, E.C. 1977. *Algas marinhas bentônicas do Brasil*. Tese de Livre Docência, Universidade de São Paulo, São Paulo, Brasil. 407p.
- OLIVEIRA, E.C. & MIRANDA, G.E.C. 1998. Aspectos sociais e econômicos da exploração de algas marinhas no Brasil. *Anais do IV Congresso Latino-Americano, II Reunião Ibero-Americana, VII Reunião Brasileira de Ficologia*, Caxambu, pp. 149-156.
- OLIVEIRA, E.C.; UGADIM, Y. & PAULA, E.J., 1979. Comunidades associadas às plantas de *Sargassum* flutuantes em águas da corrente do Brasil-Considerações biogeográficas. *Boletim de Botânica da Universidade de São Paulo*, 7: 5-9.
- PALUMBI, S.R. 2001. Humans as the world's greatest evolutionary force. *Science*, 293: 1786-1790.
- PAUL, V.J. 1997. Secondary metabolites and calcium carbonate as defenses of calcareous algae on coral reefs. *In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium*, Panamá. pp: 707-712.
- PAULA, A.F.; FIGUEIREDO, M.A.O. & CREED, J.C. 2003. Structure of the macroalgal community associated with the seagrass *Halodule wrightii* Ascherson in the Abrolhos Marine National Park, Brazil. *Botânica Marina*, 46: 413-424.
- PEDRINI, A.G. 1990. Preservation of marine benthic flora of Brazil and its habitats. *Environmental Conservation*, 17(3): 262-266.
- PEDRINI, A.G.; BRAGA, M.R.A.; UGADIM, Y. & PEREIRA, S.M.B. 1992. Algas marinhas Bentônicas do Arquipélago de Fernando de Noronha, Brasil. *Boletim de Botânica da Universidade de São Paulo*, 21: 93-101.
- PEREIRA, S.M.B. & ACCIOLY, M.C. 1998. Clorofíceas marinhas bentônicas da Praia de Serrambi, Pernambuco, Brasil. *Acta Botânica Brasílica*, 12(1): 25-52.
- PEREIRA, S.M.B.; MANSILLA, A.O.M. & COCENTINO, A.L.M. 1996. Ecological aspects of a benthic marine algal community in southeast bay, arquipélago of Fernando de Noronha, Brazil. *Trabalhos Oceanográficos da Universidade Federal de Pernambuco*, 24: 157-163.
- PICCONE, A. 1886. Nota sulle raccolte algologiche fatte durante il viaggio di circumnavigazione della "Vettor Pisani". *Notarisia*, 3: 150-151.



- PINHEIRO-JOVENTINO, F.; DANTAS, N.P. & MARASCHIN, C.D.H. 1998. Distribuição de algas marinhas no litoral de Fortaleza, Ceará, Brasil. *Arquivos de Ciência Marinha*, 31: 29-40.
- PITLIK, T.J. & PAUL, V.J. 1997. Effects of toughness, calcite level, and chemistry of crustose coralline algae (Rhodophyta, Corallinales) on grazing by the parrot fish *Clorurus sordidus*. In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 701-706.
- PITOMBO, F.B.; RATTO, C.C. & BELEM, M.J.C. 1988. Species diversity and zonation pattern of hermatypic corals at two fringing reefs of Abrolhos Archipelago, Brazil. In: Proceedings of the 6<sup>th</sup> International Coral Reef Symposium, Townsville. pp: 817-820.
- ROGERS, C.S.; GARRISON, V. & GROBER-DUNSMORE, R. 1997. A fishy story about hurricanes and herbivory: seven years of research on a reef in St. John, U. S. Virgin Islands. Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 555-560.
- RUSSELL, D.J. 1982. Introduction of *Eucheuma* to Fanning Atoll, Kiribati, for the purpose of mariculture. *Micronesica*, 18: 35-44.
- RUSSELL, D.J. 1987. Introduction and establishment of alien marine algae. *Bulletin of Marine Science*, 41: 641-642.
- SAMMARCO, P.W. 1996. Comments on coral reef regeneration, bioerosion, biogeography, and chemical ecology: future direction. *Journal of Experimental Marine Biology and Ecology*, 200: 135-168.
- SILVA, R.L.; PEREIRA, S.M.B.; OLIVEIRA, E.C. & ESTON, V.R. 1987. Structure of a bed of *Gracilaria* spp. (Rhodophyta) in northeastern Brazil. *Botanica Marina*, 30: 517-523.
- SMITH, J.E.; SMITH, C.M. & HUNTER, C.L. 2001. An experimental analysis of the effects of herbivory and nutrients enrichment on benthic community dynamics on a Hawaiian reef. *Coral Reefs*, 19: 332-342.
- SPENCER-DAVIES, P. 1992. Endosymbiosis in marine cnidarians. Plant-animal interactions in the marine benthos. In: D.M. John, S.J. Hawkins & J.H. Price, (eds.), Clarendon Press, Oxford, The Systematics Association, 45: 511-540.
- STENECK, R.S. 1986. The ecology of coralline algal crusts: convergent patterns and adaptive strategies. *Annual Review of Ecology and Systematics*, 17: 273-303
- STENECK, R.S. 1988. Herbivory on coral reefs: a synthesis. In: Proceedings of the 6<sup>th</sup> International Coral Reef Symposium, Townsville. pp: 37-49.
- STENECK, R.S. 1997. Crustose corallines, other algal functional groups, herbivores and sediments: complex interactions along reef productivity gradients. In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 7733-7738.
- STENECK, R.S. & DETHIER, M.N. 1994. A functional group approach to the structure of algal-dominated communities. *Oikos*, 69: 476-498.
- STENECK, R.S.; MACINTYRE, I.G. & REID, R.P. 1997. A unique algal ridge system in the Exuma Cays, Bahamas. *Coral Reefs*, 16: 29-37.
- STENECK, R.S. & TESTA, V. 1997. Are calcareous algae important for reefs today or in the past. In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 685-688.
- TÂMEGA, F.T.S. & FIGUEIREDO, M.A.O. 2007. Distribution of crustose coralline algae (Corallinales, Rhodophyta) in the Abrolhos reef, Bahia. *Rodriguésia*, 58(4): 941-947.
- TAYLOR, W.R. 1931. A synopsis of the marine algae of Brazil. *Revue Algologique*, 5: 279-313.
- TAYLOR, W.R. 1955. *Marine algal flora of the Caribbean and its extension into neighboring seas*. In: Essays in the Natural Sciences in honour of Captain Allan Hancock. University of South California Press, Los Angeles, pp. 259-270.
- TAYLOR, W.R. 1960. *Marine algae of the eastern tropical and subtropical coasts of the Americas*. University of Michigan Press, Michigan. 345p.
- TESTA, V. 1997. Calcareous algae and corals in the inner shelf of Rio Grande do Norte, NE, Brazil. In: Proceedings of the 8<sup>th</sup> International Coral Reef Symposium, Panamá. pp: 737-742.
- THACKER, R.W.; GINSBURG D.W. & PAUL, V.J. 2001. Effects of herbivore exclusion and nutrient enrichment on coral reef macroalgae and cyanobacteria. *Coral Reefs*, 19: 318-331.
- TORRES, J.; PEREIRA, S.M.B. & YONESHIGUE-VALENTIN, Y. 2004. Ceramiaceae (Rhodophyta) de áreas recifais do estado de Pernambuco, Brasil. *Hoehnea*, 31(2): 119-149.
- TUSSENBROEK, B.I. VAN & VIDES, L.C. 2000. Filamentous algae dominate a tropical reef community in the Mexican Caribbean: an unexpected organisation of reef vegetation. *Botanica Marina*, 43: 547-557.
- VILLAS BÔAS, A.B., FIGUEIREDO, M.A.O., VILLAÇA, R.C. 2005. Colonization and growth of crustose coralline algae (Corallinales, Rhodophyta) on the Rocas Atoll. *Brazilian Journal of Oceanography*, 53(3/4), 147-156.
- VILLAÇA, R.C. & PITOMBO, F.B. 1997. Benthic communities of shallow-water reefs of Abrolhos, Brazil. *Revista Brasileira de Oceanografia*, 45(1/2), 35-43.
- VILLAÇA, R.C.; PEDRINI, A.G.; PEREIRA, S.M.B. & FIGUEIREDO, M.A.O. 2006. Flora marinha bentônica das ilhas oceânicas brasileiras. In: R.J.V. Alves & J.W.A. Castro, (eds.), Ilhas oceânicas brasileiras: da pesquisa ao manejo. Ministério do Meio Ambiente, 1: 107-146.
- WILLIAMS, I.D. & POLUNIN, N.V.C. 2001. Large-scale associations between macroalgal cover and grazer biomass on mid-depth reefs in the Caribbean. *Coral Reefs*, 19: 358-366.

Submetido em 05/01/2008.

Aceito em 28/03/2008.