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BRIOZOOFAUNA ASSOCIADA ÀS ESPONJAS EM AMBIENTES RECIFAIS (PERNAMBUCO, BRASIL)

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Dissertação apresentada à Coordenação do Programa de Pós-Graduação em Biologia Animal da Universidade Federal de Pernambuco, como parte dos requisitos necessários à obtenção do título de mestre.

Orientador: Dr. Ulisses dos Santos Pinheiro

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RESUMO

Briozoários são organismos sésseis e coloniais, que dependem de uma superfície firme para assentamento larval e crescimento da colônia. Entre os diferentes substratos disponíveis para briozoários, as esponjas podem oferecer uma superfície favorável, trazendo muitas vantagens como a presença de compostos químicos que inibem a predação. Este estudo verificou a presença de briozoários em seis espécies de esponjas, com finalidade de avaliar a abundância e riqueza desses briozoários em diferentes esponjas. Três espécimes das esponjas, *Amphimedon compressa* Duchassaing & Michelotti, 1864, *Amphimedon viridis* Duchassaing & Michelotti, 1864, *Desmapsamma anchorata* (Carter, 1882), *Dysidea etheria* de Laubenfels, 1936, *Haliclona implexiformis* (Hechtel, 1965) e *Tedania ignis* (Duchassaing & Michelotti, 1864) foram coletadas mensalmente entre setembro de 2014 e fevereiro de 2016, em Pontas de Pedra, Pernambuco, Brasil. Os briozoários encontrados foram identificados até o menor nível taxonômico possível e quantificados. Um total de 324 espécimes de esponjas foi analisado, no qual destas 88 apresentavam briozoários em sua superfície (27%). Onze espécies de briozoários pertencentes à Classe Gymnolaemata foram encontrados nas esponjas, sendo quatro pertencentes à Ordem Ctenostomata, *Amathia distans* Busk, 1886, *Amathia verticillata* (delle Chiaje, 1822), *Amathia vidovici* Heller,1867 e *Nolella stipata* Gosse, 1855, sete da Ordem Cheilostomata, *Beania klugei* Cook, 1968, *Catenicella uberrima* (Harmer, 1957), *Caulibugula dendograpta* (Waters, 1913), *Licornia* sp., *Savignyella lafontii* (Audoin, 1826), *Synnotum aegyptiacum* Canu & Bassler, 1928 e *Thalamoporella floridana* Osburn, 1940. Briozoários foram abundantes nas esponjas *Te. ignis* e *De. anchorata* e pouco frequentes em *Ap. compressa* e *Ap. viridis*. *Desmapsamma anchorata* e *Te. ignis* apresentaram a maior riqueza de espécies (nove espécies em cada esponja), seguida por *Dy. etheria* (sete espécies). Uma baixa riqueza de espécies foi observada em *Ap. compressa*, com apenas três espécies de briozoários, *Ap. viridis* com quatro espécies, e *H. implexiformis* com cinco espécies. Apenas o briozoário *N. stipata* foi encontrado em todas as espécies de esponjas, enquanto que *At. distans* e *At. vidovici* não foram encontradas apenas em *Ap. compressa*. Uma maior riqueza e abundancia de briozoários foram encontradas em *De. anchorata* e *Te. ignis*, que apresentam superfície lisa e aveludada, e lisa e vilosa, respectivamente. Por outro lado, superfície lisa também é característica das espécies *Ap. compressa* e *Ap. viridis*, que apresentaram a menor frequência e diversidade de briozoários. Adicionalmente, as esponjas *De. anchorata* e *Dy. etheria* que apresentam superfície lisa e conulosa, respectivamente, compartilharam grande parte das espécies encontradas. A presença de metabólitos secundários nas esponjas do gênero *Amphimedon* que apresentam toxicidade já descrita na literatura, pode ter influenciado na ocorrência dos briozoários. Enquanto que as esponjas *Te. Ignis*, *De. anchorata* e *Dy. Etheria*, que apresentaram uma grande abundância de briozoários, podem ter provido um microhabitat adequado para os briozoários da região. O padrão temporal de ocorrência dos briozoários nas esponjas durante os 18 meses de coleta foi aleatório. O presente trabalho permite identificar alguns padrões da ocorrência dos briozoários, relacionado a composição química das esponjas e sua posição no substrato.

Palavras–chave: Porifera. Bryozoa. Biologia marinha. Bentos.

ABSTRACT

Bryozoans comprise sessile, colonial organisms that require a hard surface for settlement and growth. Among different substrata for bryozoans, sponges may provide suitable substrata, with advantages such as presence of compounds against predators. This study analyses the bryozoan community on six sponges species throughout 18 months, to evaluate the presence of bryozoans on its surface. Three specimens of each sponges, *Amphimedon compressa* Duchassaing & Michelotti, 1864, *Amphimedon viridis* Duchassaing & Michelotti, 1864, *Desmapsamma anchorata* (Carter, 1882), *Dysidea etheria* de Laubenfels, 1936, *Haliclona implexiformis* (Hechtel, 1965) and *Tedania ignis* (Duchassaing & Michelotti, 1864), were taken monthly betweem September 2014 to February 2016, in Pontas de Pedra, Pernambuco State, Brazil. Bryozoans were identified to the lowest taxonomic level, and quantified. Total of 324 specimens of sponges were analysed, 88 from those were found bryozoans on its surface (27%). Eleven gymnolaemate bryozoans were found on sponges being four of the Order Ctenostomata, *Amathia distans* Busk, 1886, *Amathia verticillata* (delle Chiaje, 1822), *Amathia vidovici* Heller,1867 and *Nolella stipata* Gosse, 1855, and seven species Cheilostomata, *Beania klugei* Cook, 1968, *Catenicella uberrima* (Harmer, 1957), *Caulibugula dendograpta* (Waters, 1913), *Licornia* sp., *Savignyella lafontii* (Audoin, 1826), *Synnotum aegyptiacum* Canu & Bassler, 1928 and *Thalamoporella floridana* Osburn, 1940. Bryozoans were considered abundant on the sponges *Te*. *ignis* and *De*. *anchorata*, but few frequents on *Ap*. *compressa* and *Ap*. *viridis*. On *De. anchorata* and *Te*. *ignis* were found the highest bryozoan richness (9 species of bryozoan per sponge species), followed by *Dy*. *etheria* (7 bryozoan species). A low species richness was observed in *Ap*. *compressa*, *Ap*. *viridis* and *H*. *implexiformis* with respectively three, four and five species of bryozoans on their surface. Only *N. stipata* was found on the six sponge species, while *At*. *distans* and *At*. *vidovici* were not found only on *Ap. compressa*. Higher richness and abundance of bryozoans were found in *De*. *anchorata* and *Te*. *ignis*, with smooth and velvety surface, smooth and villous surface, respectively. Smooth surface is also characteristic of *Ap*. *compressa* and *Ap*. *viridis*, with the lowest frequency and diversity of bryozoans. Additionally, on sponges *De*. *anchorata* and *Dy*. *etheria*, with smooth and conulose surface respectively, were shared the majority of bryozoan species. We suggest the presence of secondary metabolites may have interfered the bryozoans on sponges of *Amphimedon* genus. Sponges *Te*. *ignis*, *De*. *anchorata* and *Dy*. *etheria*, have an abundance of bryozoans; thus, we suggest these sponges may allow a suitable substratum for the bryozoans. The temporal variation of bryozoans on sponges was random. In present work some patterns of occurrence of bryozoans are presented, with relation to the chemical composition and position of sponge.

Key words: Porifera. Bryozoa. Marine biology. Benthos.

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1 INTRODUÇÃO

Os poríferos são definidos como metazoários sésseis com um diferenciado sistema aquífero (HOOPER et al., 2002). O plano corporal dos poríferos é simples, consistindo de uma série de câmaras e canais através dos quais a água circula (ERWIN & THACKER, 2007). Seu corpo é organizado em três camadas: a pinacoderme composta por células superficiais, os pinacócitos; o mesoílo, matriz fundamental de fibrilas de colágeno, associada a elementos esqueléticos e células denominadas amebócitos; e a coanoderme, composta por coanócitos, células flageladas das esponjas (HAJDU et al., 2011). Estes contêm uma população altamente móvel de células capazes de se diferenciar em outros tipos de células (totipotentes), conferindo uma plasticidade de forma de crescimento (HOOPER et al., 2002).

As esponjas possuem um papel primordial na manutenção da biodiversidade bentônica marinha, incluindo a estruturação física do ecossistema (MORAES, 2011). Devido aos seus sistemas de canais, abrigam uma grande diversidade de organismos (HAJDU et al., 2011), sua estrutura homogênea, maleável e simples pode favorecer interações simbióticas com outros táxons (WULFF, 2006). Eles também produzem compostos secundários contra predação e anti-incrustação (HAJDU et al., 2011), o que pode favorecer ou não a relação com outros grupos.

Sua relativa simplicidade estrutural é comumente associada a uma suposta alta adaptabilidade, o que lhes confere papel de destaque na competição por substrato, sendo frequentemente dominantes em ambientes consolidados (substrato duro) e de iluminação moderada à ausente (HAJDU et al., 2011). Algumas espécies já foram reportadas como competidores por espaço em recifes de corais (WULLF, 2001), porém essa competição entre espécies de esponjas raramente foi demonstrada (WULFF, 2006).

Em geral, esponjas marinhas podem abrigar diferentes organismos com relações distintas, incluindo comensalismo (FORESTER, 1979; POND, 1992), mutualismo (WULFF, 1997), e até relações parasitárias (BACESCU, 1971). Esponjas provém um bom substrato consolidado, adequado para fauna bentônica em um ambiente aberto e com sedimentos (KLITGAARD, 1995). Muitas vantagens em associações com esponjas foram reportadas, como proteção contra predadores, prover um ambiente seguro para a reprodução, abrigo e fornecedor de alimentos (DUARTE & NALESSO, 1996; RIBEIRO et al., 2003).

As diferentes morfologias apresentadas pelas esponjas podem ser favoráveis a essas relações com outros organismos. Bell & Barnes (2001) constataram uma correlação positiva entre a diversidade morfológica das esponjas, comparando espécies de forma incrustante, maciça, globular, pedunculada, tubular, flabelada, reptante, arborescente e papilar, e a diversidade de espécies associadas encontradas nessas esponjas. Já no estudo de Klitgaard (1995), a autora propôs que a morfologia como também a influência de metabólitos secundários das esponjas podem ser fatores determinantes na composição da fauna associada em águas temperadas e tropicais quentes. Em outro trabalho, Puce et al. (2005) sugeriu que algumas espécies de hidróides associados as esponjas, conseguiram superar as defesas químicas que impedem o assentamento de outros organismos nas esponjas. Neste sentido, estes hidróides recebem proteção para colônia contra predação por nudibrânquios e do crescimento de outros organismos bentônicos sob a colônia (PUCE et al., 2005).

Alguns estudos descrevem a variação temporal da macrofauna associada as esponjas, bem como a possível influência de fatores ambientais (ÁVILA & ORTEGA-BATISTA, 2014). Biernbaum (1981) verificou que as plumas de águas temperadas influenciaram nas mudanças sazonais da densidade de anfípodes em quatro espécies de esponjas. Em contraste, a macrofauna associada à esponja *Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004, não apresentou variação sazonal entre o período seco e chuvoso. Contudo, os autores indicaram que algumas mudanças ambientais, como salinidade, temperatura e disponibilidade de alimento na água, podem influenciar a composição da fauna associada (PÁDUA et al., 2012).

Existem muitos estudos sobre interações de organismos com uma única espécie de esponja (CUARTAS & EXCOFFON, 1993; DUARTE & NALESSO, 1996; RIBEIRO et al., 2003; HUANG et al., 2008; STOFEL et al., 2008; PÁDUA et al., 2012; ÁVILA & ORTEGA-BASTIDA, 2014), frequentemente com organismos associados tratados em nível de grandes grupos. Mas, apenas poucos estudos comparando diferentes espécies de esponjas com os organismos associados (BIERNBAUM, 1981; KLITGAARD, 1995; NEVES & OMENA, 2003; CAMPOS et al., 2012). Neves & Omena (2003) foi observaram que diferentes espécies de esponjas possuem uma relação entre a sua morfologia (incrustante, lobada e maciça) com a densidade de poliquetas associados. Campos et al. (2012), investigou o grau de seleção substrato pelo hidrozoário *Zyzzyzus warreni* Calder, 1988, em seis espécies de esponjas, e pôde observar que a esponja *Amphimedon viridis* Duchassaing & Michelotti, 1864 apresentou 100% de letalidade, enquanto que um assentamento larval elevado e de curta duração, foi encontrado em actinulas expostas a esponja *Tedania ignis* (Duchassaing & Michelotti, 1864).

Entre os diferentes grupos de invertebrados associados às esponjas, os briozoários estão entre os menos relatados (KLITGAARD, 1995; VIEIRA et al., 2012). Briozoários são geralmente coloniais, formados por unidades funcionalmente independentes (zoóides), que dependem de uma superfície para fixação da larva e desenvolvimento da colônia (MIGOTTO et al., 2011). Compreendem um grupo comum a vários tipos de habitats, incluindo regiões portuárias, zonas entremarés e águas profundas, sobre substratos artificiais e naturais (VIEIRA et al., 2016a). Basicamente, as colônias podem apresentar formas incrustantes laminares ou arborescentes e eretas (WINSTON, 1982), cuja a aparência da colônia varia desde uma massa gelatinosa até formas coralinas fortemente calcificadas (HADDAD et al., 2004).

O filo Bryozoa inclui três classes: Phylactolaemata Allman, 1856, Stenolaemata Borg, 1941 e Gymnolaemata Allman, 1856 (BOCK & GORDON, 2013). Atualmente cerca de 8.800 espécies são conhecidas no mundo (BOCK, 2014), sendo mais de 450 espécies registradas para o Brasil (VIEIRA et al., 2016b). Os briozoários apresentam uma considerável riqueza de espécies no ambiente marinho, geralmente com colônias pequenas e crípticas, podendo ser ainda facilmente confundido com outros organismos como algas e cnidários (MIGOTTO et al., 2011).

Diversas espécies de briozoários são utilizadas como indicadores ecológicos e bioindicadores de poluição, com espécies relacionadas com problemas de bioinvasão marinha (ELIA et al., 2007; PIOLA & JOHNSTON, 2009; IGNACIO et al., 2010). Mudanças na diversidade da fauna de briozoários em uma grande escala de tempo foram encontradas na Baía de Veneza, inclusive com a presença de espécies invasoras (CORRIERO et al., 2007). Os briozoários, assim, ocupam um nicho importante no ambiente marinho e, por serem abundantes, podem ser utilizados como indicadores de diversidade, interagindo com outros invertebrados, tais como corais e esponjas (VIEIRA et al., 2012).

Em um ambiente com escassez de substrato adequado para briozoários, as esponjas podem proporcionar um substrato mais propicio para o assentamento larval (KLITGAARD, 1995). Há pelo menos dois importantes fatores ambientais que controlam a distribuição dos briozoários, que incluem a presença de uma superfície adequada para o estabelecimento larval e para o crescimento da colônia, e a variedade de microhabitats disponíveis (WINSTON, 1982). Associações com briozoários, no entanto, podem estar relacionadas com as diferentes condições de temperatura, salinidade, turbidez, deposição de sedimentos, e disponibilidade de substrato, que permitem a eles a colonização de diferentes substratos (COOK, 1985). A associação entre briozoários e substrato também pode ser favorecida por estruturas especializadas da colônia (VIEIRA & STAMPAR, 2014), promovendo relações específicas entre eles, como associações de substrato.

Interações dos briozoários com outros grupos biológicos são registrados em alguns estudos, apresentando diferentes substratos como: algas (ROGICK & CROASDALE, 1949; WINSTON, 1982; KUKLIŃSKI & BARNES, 2005); cnidários (WINSTON, 1982; KUKLIŃSKI & BARNES, 2005; VIEIRA & STAMPAR, 2014); braquiúros (ABELLÓ & CORBERA, 1996; KEY et al., 1999); foraminíferos (BERNING et al., 2009); picnogonídeos (KEY et al., 2013); conchas de gastrópodes (WINSTON, 1982; CARTER & GORDON, 2007); e esponjas (KLITGAARD, 1995; RIBEIRO et al., 2003; ISETO et al., 2008; VIEIRA et al., 2012; PÁDUA et al., 2012; ALMEIDA & SOUZA, 2014; CAVALCANTI et al., 2015). No Brasil, no entanto, associações entre esponjas e briozoários foram reportados em poucos estudos (VIEIRA et al., 2012; PÁDUA et al., 2012; ALMEIDA & SOUZA, 2014; CAVALCANTI et al., 2015), mas estudos que envolvem variações temporais, morfologia e composição química da esponja, com a ocorrência de briozoários sobre esponjas ainda não foram realizados.

2 OBJETIVOS

2.1 Objetivo geral

- Investigar a ocorrência e abundância da fauna de briozoários encontrados em seis espécies de esponjas nos recifes de Pontas de Pedra, Pernambuco, Brasil.

2.2 Objetivos específicos

- Avaliar se fatores como forma e composição química das esponjas favorecem a associação com os briozoários;
- Verificar a presença de estruturas adaptativas (cenozoóides e rizóides) dos briozoários para associação com esponjas;
- Inventariar os briozoários em Pontas de Pedra (PE), identificando suas associações com esponja;
- Verificar a ocorrência de briozoários férteis sobre as seis espécies de esponjas.

3 HIPÓTESES

H1: O tipo de superfície e a composição (toxicidade) da esponja influenciam a ocorrência de briozoários nas esponjas;

H2: Existem padrões temporais bem definidos (estação seca e chuvosa) na ocorrência de briozoários nas esponjas.

4 CAPÍTULO 1

Este capítulo contém o artigo intitulado:

Associations and temporal variation between bryozoans and sponges in Pernambuco, NE Brazil

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Associations and temporal variation between bryozoans and sponges in Pernambuco, NE Brazil

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Abstract Bryozoans comprise sessile, colonial organisms that need a hard surface for settlement and growth. Among different substrata for bryozoans, sponges may provide suitable substrata, with many advantages due presence of compounds against predators. This study analyses the bryozoan community on six species of sponges throughout 18 months, to evaluate the presence of bryozoans on its surface. Eleven bryozoan species were found, only gymnolaemates, four of them belong to the Order Ctenostomata and seven species to the Order Cheilostomata. Bryozoans were abundant on sponges *Tedania ignis* (Duchassaing & Michelotti, 1864) and *Desmapsamma anchorata* (Carter, 1882), but less frequent on *Amphimedon compressa* Duchassaing & Michelotti, 1864 and *Amphimedon viridis* Duchassaing & Michelotti, 1864. The frequency-occurrence was similar to other sponges, with a predominance of one species per sample (sponge). Bryozoans on sponges were identified and quantified, and a multidimensional scaling (MDS) ordination were done using Sorensen's association coefficient, that was perfomed to visualize the relationships among sponges and months. No pattern between sponge surface and occurrence of bryozoan species was observed, but we suggest that the presence of secondary metabolites could have inhibited bryozoans on sponges of genus *Amphimedon*. The occurrence of bryozoans on sponges was random during 18 months of sampling.

Keywords: Bryozoans, invertebrates, benthos, Porifera, association.

Introduction

Marine sponges constitute one of the richest biotopes in tropical seas (Bacescu, 1971). The general sponge structure, homogeneous, malleable, and simple, with many internal canals, may facilitate development of intimate associations with other organisms (Wulff, 2006). Thus, marine sponges may host different organisms with different interactions, including commensal (Forester, 1979; Pond, 1992), mutual (Wulff, 1997) and even parasitic relationships (Bavestrello et al., 2000). Sponges may provide suitable substrata, which many advantages providing protection against predators, safe environment for reproduction for other organisms, shelter, and food supply (Duarte & Nalesso, 1996; Ribeiro et al., 2003).

Only few studies were carried on the temporal variability of the macrofaunal assemblages associated with sponges and on the environmental factors that influence these variations (Ávila & Ortega-Batista, 2014). Water temperature may be an important factor influencing the seasonal changes in associated biota in sponges (Biernbaum, 1981), but there are other environmental changes, including salinity, temperature or food availability, that also may influence these associations (Pádua et al., 2012).

Majority of studies on association between macrofaunal assemblages and sponges include a single sponge species (e.g. Cuartas & Excoffon, 1993; Duarte & Nalesso, 1996; Ribeiro et al., 2003; Huang et al., 2008; Stofel et al., 2008; Pádua et al., 2012; Avila & Ortega-Bastida, 2014), with only few studies comparing different sponge species and their hosts (Biernbaum, 1981; Klitgaard, 1995; Neves & Omena, 2003; Campos et al., 2012). Klitgaard (1995) suggests that sponge morphology and presence of secondary metabolites may have influence in the associated fauna. Despite the presence of chemical compounds in some sponges, these may be favorable for associated encrusting biota against predation and overgrowth by other benthic organism (Puce et al., 2005). Thus, sponges comprise good hard substrata for other benthic organisms, including bryozoans, in a soft bottom area with scarcity of suitable substratum (Klitgaard, 1995).

Bryozoans are a typical component of sessil assemblages with high species diversity, large size range, and occupying different habitats (Cook, 1985). Nevertheless, they may recruit in a specific substratum position. They have different sizes, and live in colonies ranging from a few individuals to hundreds, with different organizations and ramifications.

There are at least two important environmental controls on the bryozoan distribution, including the presence of a suitable surface for larval settlement and colony growth, and the associated category of variety of available microhabitats (Winston, 1982). Bryozoan associations, however, may also be related to different conditions of temperature, salinity, turbulence, sediment deposition, and the substrata availability, that allow then to colonize different substrata (Cook, 1985). The association between bryozoan and substratum may also be favored by colony specialized structures (Vieira & Stampar, 2014), promoting specific relations between them.

Interactions with bryozoans and other biological groups were registered in some studies involving as substrata: algae (Rogick & Croasdale, 1949; Winston, 1982; Kukliński & Barnes, 2005); anemones and hydroids (Winston, 1982; Kukliński & Barnes, 2005; Vieira & Stampar, 2014); brachyuran (Abelló & Corbera, 1996; Key et al., 1999); foraminifera (Berning et al., 2009); pycnogonids (Key et al., 2013); shells (Winston, 1982; Carter & Gordon, 2007); and sponges (Klitgaard, 1995; Ribeiro et al., 2003; Iseto et al., 2008; Vieira et al., 2012; Pádua et al., 2012; Almeida & Souza, 2014; Cavalcanti et al., 2015). In Brazil, however, associations between sponges and bryozoans have been reported in few studies (Vieira et al., 2012; Pádua et al., 2012; Almeida & Souza, 2014; Cavalcanti et al., 2015), but studies that involve temporal variation, the sponge morphology and composition, with the occurrence of bryozoans on sponges were not performed.

Here we investigate the occurrence and abundance of bryozoan fauna on six species of sponges. We also compare if the surface and presence of secondary metabolites in sponges may have influence in bryozoan community, and if there are any temporal variation in this community along 18 months of sampling.

Materials and Methods

Study area and sampling

The study area is located on reefs from Pontas de Pedra Beach (07°37’00’’S – 34°48’51’’W), Pernambuco, Brazil (Fig. 1). Its origin dated from Tertiary with the formation of large barriers, and is composed of beachrocks of elongated and discontinuous bodies (Dominguez et al., 1990). During low tide the local depth varies between -0.1 to 0.4 meters (Fig. 2).

The samplings were taken monthly from September 2014 to February 2016, during low spring tides. Six species of sponges (Fig. 3) with different characteristics were selected in this study (Tab. 1). Three random individual of each sponge species were collect manually by free diving from intertidal zone to maximum of one-meter depth, with a minimum distance of five meters between each specimen; reaching a total of 324 samples, 54 for each species. During sampling, physicochemical parameters of the water were verified—temperature, dissolved oxygen, water pH and salinity—for environmental characterization, using an YSI multiparameter sonde (YSI Professional Plus Instrument). Rainfall data from Pontas de Pedra Beach were obtained through the website of Water and Climage Agency of Pernambuco (*Agência Pernambucana de Águas e Clima*, APAC).

Each sponge specimen was preserved in 80% ethanol and a voucher of each species (Tab. 1) was deposited in the Porifera Collection at the Universidade Federal de Pernambuco (UFPEPOR). Bryozoan specimens were deposited in the bryozoan collection at the Universidade Federal de Pernambuco (UFPEBRY). The bryozoans were observed and identified using stereomicroscopy (ZEISS Stemi 2000 C). For each bryozoan were observed presence of fastening structures or kenozooids, and presence of embryos.

Abreviations are: PP = Pontas de Pedra; PE = Pernambuco State; PB = Paraíba State; AL = Alagoas State; sep = September; oct = October; nov = November; dec = December; jan = January; fev = February; mar = March; apr = April; may = May; jun = June; jul = July; aug = August.

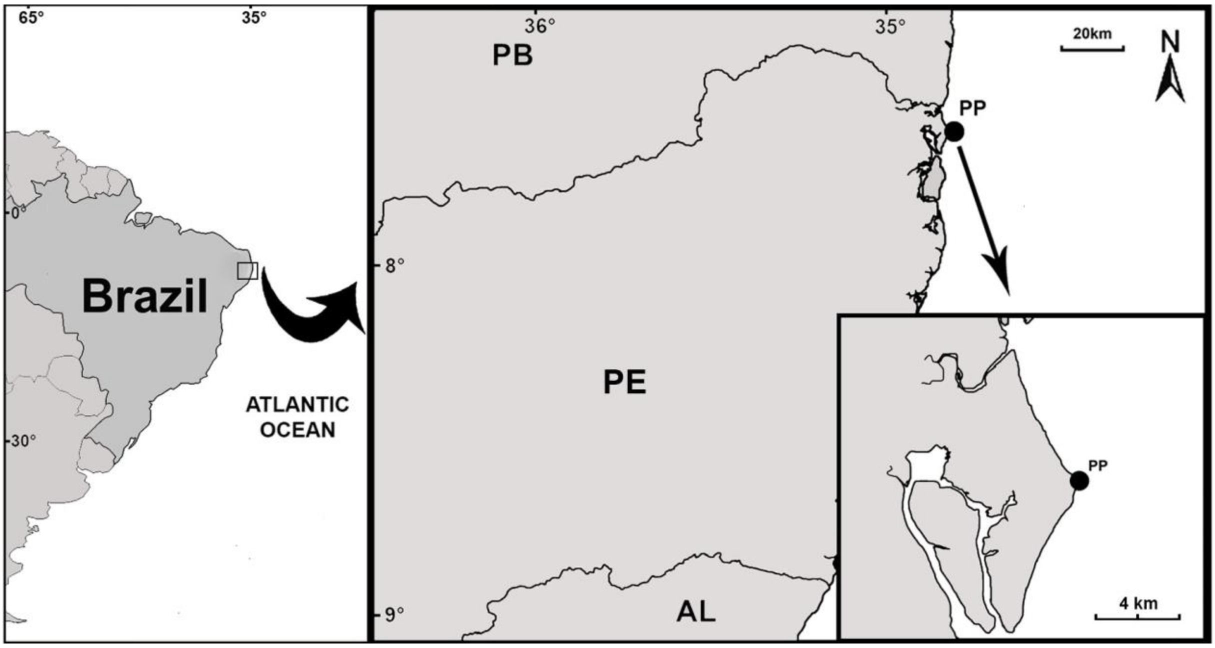

Fig. 1 Location of the study, Pontas de Pedra, Pernambuco State, Northeastern Brazil.

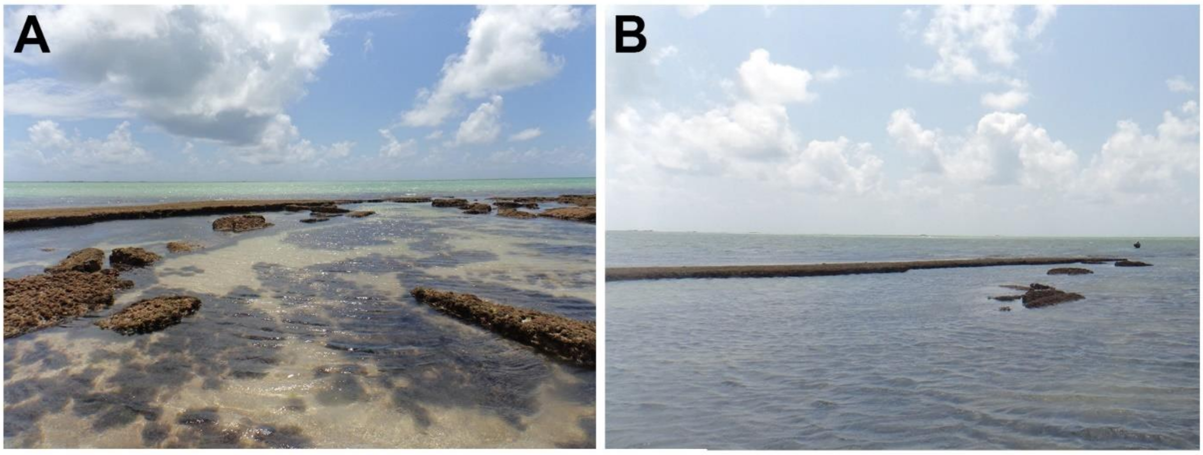

Fig. 2 Features of collecting location of bryozoan-porifera association, Pontas de Pedra, northeastern of Brazil. A, exposing beachrochs; B, location during high tide.

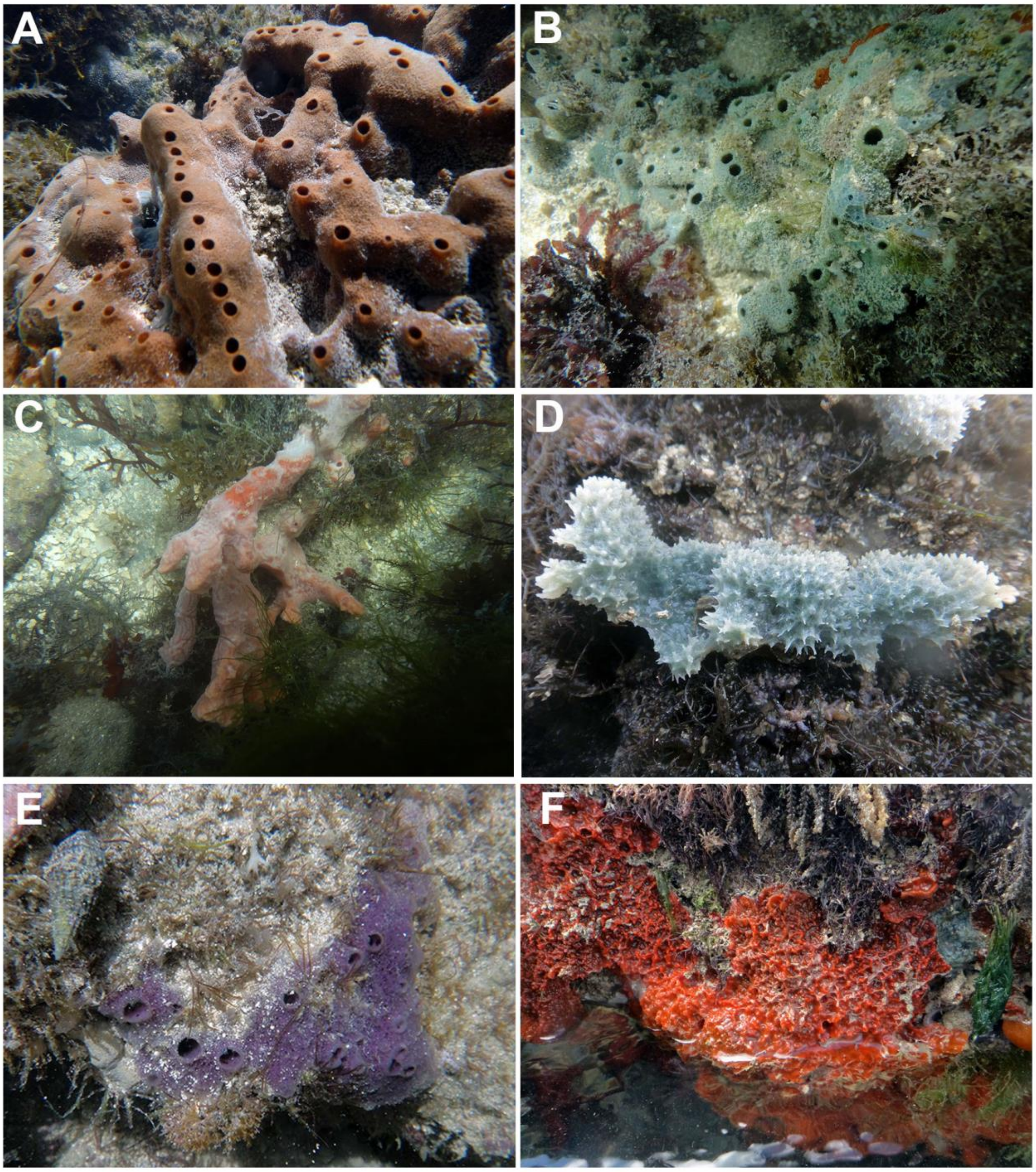

Fig. 3 Sponges collected during sampling in Pontas de Pedra, Pernambuco, Northeastern Brazil. A, *Amphimedon compressa* Duchassaing & Michelotti, 1864; B, *Amphimedon viridis* Duchassaing & Michelotti, 1864; C, *Desmapsamma anchorata* (Carter, 1882); D, *Dysidea etheria* de Laubenfels, 1936; E, *Haliclona* (*Reniera*) *implexiformis* (Hechtel, 1965); F, *Tedania* (*Tedania*) *ignis* (Duchassaing & Michelotti, 1864).

Table 1 Distribution, shape and composition of sponges species included in present study.

Sponge species [Voucher No. UFPEPOR]	Distribution	Surface	Color	Secundary metabolites
Amphimedon compressa Duchassaing & Michelotti, 1864 / [2054]	Western Atlantic [1,2]	Smooth and microhispid[1]	Dark brown[1]	Present[8,9]
Amphimedon viridis Duchassaing & Michelotti, 1864 [2052]	Western Atlantic [1,2]	Smooth and microhispid[1]	Green[1]	Present[10,11,12,13]
Desmapsamma anchorata (Carter, 1882) [2051]	Western Atlantic[2,3]	Smooth and velvety[3,4]	Pale purplish-pink[3,4]	Unkown
Dysidea etheria de Laubenfels, 1936 [2055]	Western Atlantic[2,5]	Irregular conulose[5,6]	Blue or purple[5,6]	Present[14]
Haliclona implexiformis (Hechtel, 1965) [2053]	Caribbean, Northeastern Brazil[1,7]	Smooth[1,4]	Reddish or bluish purple[1,4]	Unkown
Tedania ignis (Duchassaing & Michelotti, 1864) [2050]	Western Atlantic[2,3]	Smooth, tuberculate or villous[3]	Red to orange[3,4,6]	Present[15,16]

References: (1) Van Soest (1980); (2) Muricy et al. (2011); (3) Van Soest (1984); (4) Hajdu et al. (2011); (5) Van Soest (1978); (6) Moraes (2011); (7) Weerdt (2000); (8) Albrysio et al. (1995); (9) Kelly et al. (2003); (10) Berlinck et al. (1996); (11) Berlinck et al. (2004); (12) Campos et al. (2012); (13) Kelman et al. (2001); (14) Gunasekera et al. (1996); (15) Schmitz et al. (1984); (16) Muricy & Hajdu (2006).

Statistical analysis

The frequency of occurrence patterns (*F*) of bryozoans was defined according to number of samples of each sponge, where $F = n_1 \times n^{-1}$ (*F* is the frequency of taxa in %; n_1 is the number of samples and n = 54, which it is the number of all samples). Thus, it was considered: <2% rare; ≥2 <10% less frequent; ≥10% <20% regular; ≥20% <30% frequent; ≥30% dominant.

The estimated amount of bryozoan colonies present in each sponge was given from the number of colonies present. Therefore, between 1–4 colonies was adopted (+); between 5–9 colonies (++); and ≥10 (+++).

Significant differences among sponge and bryozoan species found in samples were tested by chi- square test. Presence and absence analysis of bryozoans were verified. A multidimensional scaling (MDS) ordination of Sorensen similarity matrix was used to visualize the relationships among sponges, months and position of sponges in beachrocks (e.g under beachrocks, exposed to sunlight); samples with exclusive ocurrency of one bryozoan species on a single sponge species was excluded from analyses. The total number of samples of sponges were compared with Cluster of Bray-Curtis similarity. Differences in bryozoan fauna composition between groups of sponges were tested using a one-way analysis of similarities (ANOSIM) based on Sorensen similarity. The analyses described above were performed with Primer® 6.0. software.

Results

The temperature of water ranged from 32.1°C (April/2015) to 26.6°C (July/2015) and salinity from 42.5 (April/2015) to 33.7 (January/2016). Other physicochemical parameters data of the water is given on figure 4. The maximum rainfall was in March/2015 (450.2 mm) and the minimum in November/2015 (12.4 mm) (Fig. 5).

Pontas de Pedra is a heterogeneous environment, composed of microhabitats such as crevices, holes and caves. The suitable habitats for bryozoans are small reentrances or below the beachrocks, with no direct exposition to sunlight. The sponges *Amphimedon compressa*, *Ap. viridis* and *Te. ignis* were colleted under the beachrocks, in sciaphilous habitat (Fig. 6). *Dysidea etheria* were found near interface beachrock-sand close to two *Amphimedon* species and *Te. ignis* (Fig. 6). *Desmapsamma anchorata* were collected in a sand sciaphilous microhabitat near to rocks (Fig. 6). Sampling of *H. implexiformis* was done near beachroacks border, exposed to sun (Fig. 6).

Only gymnolaemats bryozoans were found on sponges, four of those belong to Order Ctenostomata and seven species of Order Cheilostomata (Tab. 2). Only *Thalamoporella floridana* Osburn, 1940 and *Nolella stipata* Gosse, 1855 have encrusting laminar colonies, while the other species have mainly erect and articulate colonies. Fastening structures (kenozooids or stolons) are found in all erect colonies, while the encrusting *N. stipata* has encrusting stoloniform prolongations connecting autozooids (Vieira et al., 2014). In the samples, embryos were seen in *Licornia* sp. and *Savignyella lafontii* (Audoin, 1826), while young colonies were only found in *Amathia verticillata* (delle Chiaje, 1822) (Tab. 2).

Bryozoan species were found in 88 samples (27%), with significant difference among sponge species (χ^2=53.2, p<0.01) (Tab. 3). They showed higher frequency-occurrence on *Te. ignis,* being found on the surface of 31 samples, 57.4%, followed by *Desmapsamma anchorata*, with 25 samples. *Ap. compressa* and *Ap. viridis*, with only three samples (5.6%) and 4 samples (7.4%) respectively, presented the lowest bryozoan frequency.

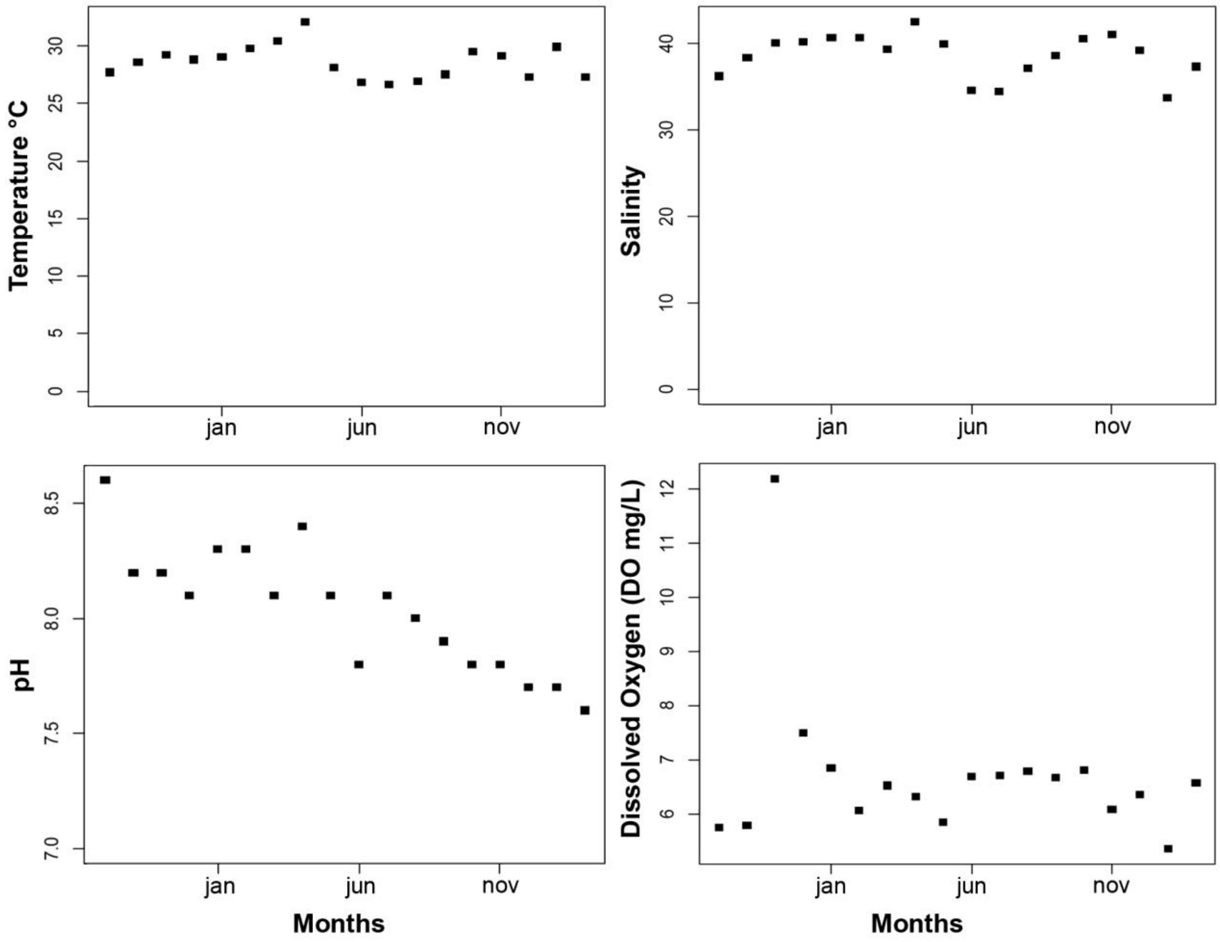

Fig. 4 Environmental parameters obtained between September 2014 and February 2016 in Pontas de Pedra, Pernambuco, Northeastern Brazil. The months correspond jan = January/2015, jun = June/2015, nov = November/2015.

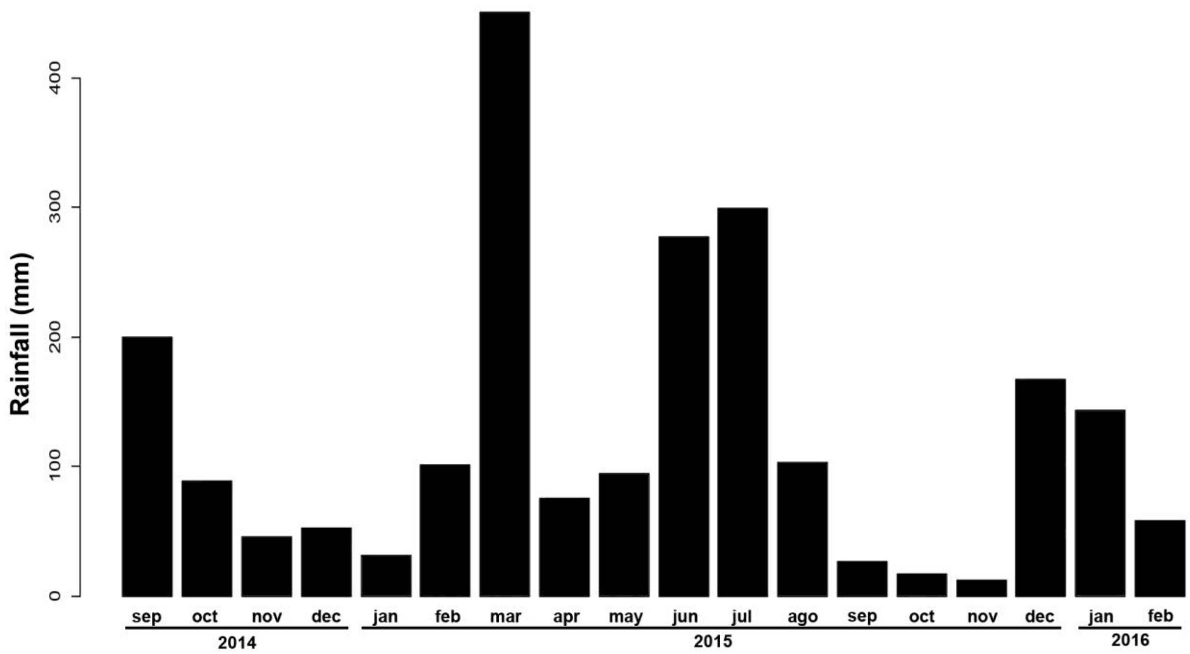

Fig. 5 Rainfall data accumulated between months during sampling in Pontas de Pedra, Pernambuco, Northeastern Brazil, obtained through the website of Water and Climage Agency of Pernambuco (APAC).

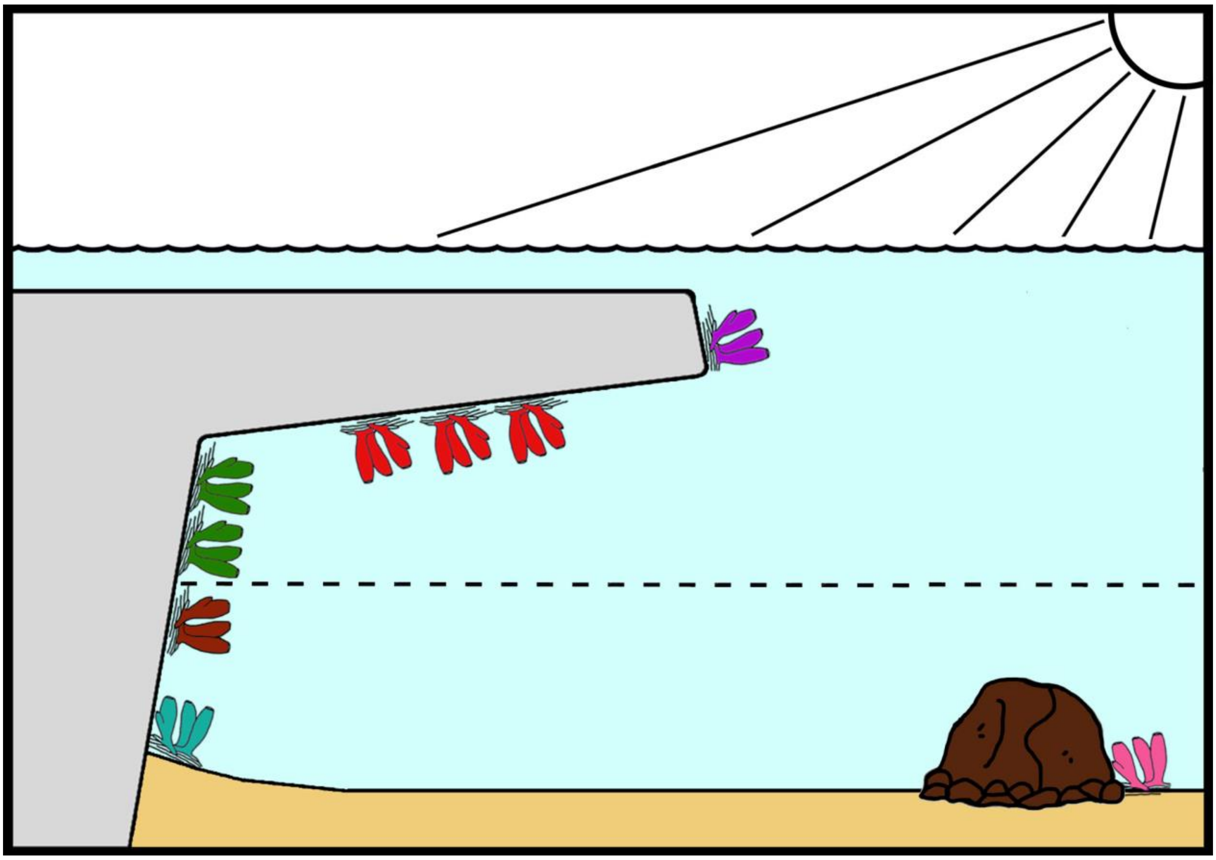

Fig. 6 Position of each sponge species including in present study on the beachrocks of Pontas de Pedra, Pernambuco, Northeastern Brazil. The sponge *Haliclona implexiformis* is represented by the color purple, *Tedania ignis* in red, *Amphimedon viridis* in green, *Amphimedon compressa* in brown, *Dysidea etheria* in blue and *Desmapsamma anchorata* in pink. The dashed line indicates the low tide during sampling.

Table 2 Characteristics of bryozoans collected on sponges in Pontas de Pedra, Pernambuco, Northeastern Brazil, including colony shape, anchoring kenozooids (A, absent; B, rhizoids in proximal part of the colony; C, rhizoids at the abfrontal surface of the zooid) and reproductive colonies.

Bryozoan species	**Colony shape**	**Anchoring kenozooid**	**Embryos or young settled colonies**
Order Ctenostomata			
Amathia distans Busk, 1886	Erect	B	-
Amathia verticillata (delle Chiaje, 1822)	Erect	A	young colonies [Jul/15 and Feb/16]
Amathia vidovici Heller,1867	Erect	B	-
Nolella stipata Gosse, 1855	encrusting	A	-
Order Cheilostomata			
Beania klugei Cook, 1968	Erect	C	-
Catenicella uberrima (Harmer, 1957)	Erect	C	-
Caulibugula dendograpta (Waters, 1913)	Erect	B	-
Licornia sp.	Erect	C	embryos [Sep/14–Feb/15, Jul/15, Nov/15–Jan/16]
Savignyella lafontii (Audoin, 1826)	Erect	C	embryos [Feb/15 and Oct/15]
Synnotum aegyptiacum Canu & Bassler, 1928	erect	B	-
Thalamoporella floridana Osburn, 1940	encrusting	A	-

Desmapsamma anchorata and *Te*. *ignis* have highest bryozoan richness (nine species each), followed by *Dy*. *etheria* (seven species). Low species richness was observed on *Ap*. *compressa* (three species), *Ap*. *viridis* (four species), and *H*. *implexiformis* (five species). The richness of bryozoan per sample was considered low, with majority of samples (48) with a single bryozoan species, and a single sample with six bryozoan species (major species richness found) (Tab. 3).

Nolella stipata was found on all sponge species, while *At. distans* and *At. vidovici* were absent only on the sponge *Ap. compressa*. The encrusting bryozoan *Th. floridana* was found only on *Ap. compressa* and *De. anchorata*. Three bryozoan species were found on a single sponge species, of those *At*. *verticillata* and *B. klugei* were found exclusively on *Te. ignis*, while *Ct. uberrima* was found only on *De. anchorata*.

Two bryozoans were considered rare in samples, *B*. *klugei* and *Ct*. *uberrima*, with a single colony on this study. *Licornia* sp. and *N. stipata* are the most common species in total samples, occuring respectively on 40 and 30 samples. All bryozoans found on sponges *Ap*. *compressa*, *Ap*. *viridis* and *H*. *implexiformis* were rare or less frequent (Tab. 3). Over the sponge *De*. *anchorata*, only the bryozoans *Cl. dendograpta*, *Ct*. *uberrima*, *N*. *stipata* and *Th*. *floridana* were rare, while *Licornia* sp. was considered dominant (Tab. 3). On sponge *Dy*. *etheria*, the bryozoan *Sy*. *aegyptiacum* and *Licornia* sp. were considered rare and frequent, respectively (Tab. 3). On the sponge *Te*. *ignis*, the bryozoan *B*. *klugei* was considered rare, *At. vidovici* was frequent and *N*. *stipata* was dominant (Tab. 3).

The abundance of bryozoans on sponges was estimated according to number of colonies present on sponges. Some species such as *Licornia* sp. and *Amathia* spp. have large colonies and cover majority of the sponge surface (Fig. 7). Other species, such as *Sa*. *lafontii* and *Sy*. *aegyptiacum*, have small delicate colonies, but were considered abundant on sponges. Thus, it was possible verified the sponges *Ap*. *compressa* and *Ap*. *viridis* with few colonies over them, while *De*. *anchorata* and *Te*. *ignis* were found with many colonies of bryozoan species (Fig. 7; Tab. 4).

Table 3 Richness and frequency of occurrence (between parenthesis) of bryozoans on sponges during 18 months of sampling (n = 54 samples per sponge species).

Sponges / **Bryozoans**	***Amphimedon compressa***	***Amphimedon viridis***	***Desmapsamma anchorata***	***Dysidea etheria***	***Haliclona implexiformis***	***Tedania ignis***
Amathia distans	0	1 (1.9%)	9 (16.7%)	8 (14.8%)	1 (1.9%)	6 (11.1%)
Amathia verticillata	0	0	0	0	0	6 (11.1%)
Amathia vidovici	0	1 (1.9%)	2 (3.7%)	4 (7.4%)	2 (3.7%)	15 (27.8%)
Beania klugei	0	0	0	0	0	1 (1.9%)
Catenicella uberrima	0	0	1 (1.9%)	0	0	0
Caulibugula dendograpta	0	0	1 (1.9%)	2 (3.7%)	0	2 (3.7%)
Licornia sp.	2 (3.7%)	0	20 (37.0%)	12 (22.2%)	0	6 (11.1%)
Nolella stipata	1 (1.9%)	1 (1.9%)	1 (1.9%)	3 (5.6%)	5 (9.3%)	19 (35.2%)
Savignyella lafontii	0	2 (3.7%)	7 (13.0%)	4 (7.4%)	3 (5.6%)	8 (14.8%)
Synnotum aegyptiacum	0	0	3 (5.6%)	1 (1.9%)	4 (7.4%)	7 (13.0%)
Thalamoporella floridana	1 (1.9%)	0	1 (1.9%)	0	0	0
Total Richness	3	4	9	7	5	9
Sponges specimens with bryozoans	3 (5.6%)	4 (7.4%)	25 (46.3 %)	18 (33.3%)	7 (13.0%)	31 (57.4%)

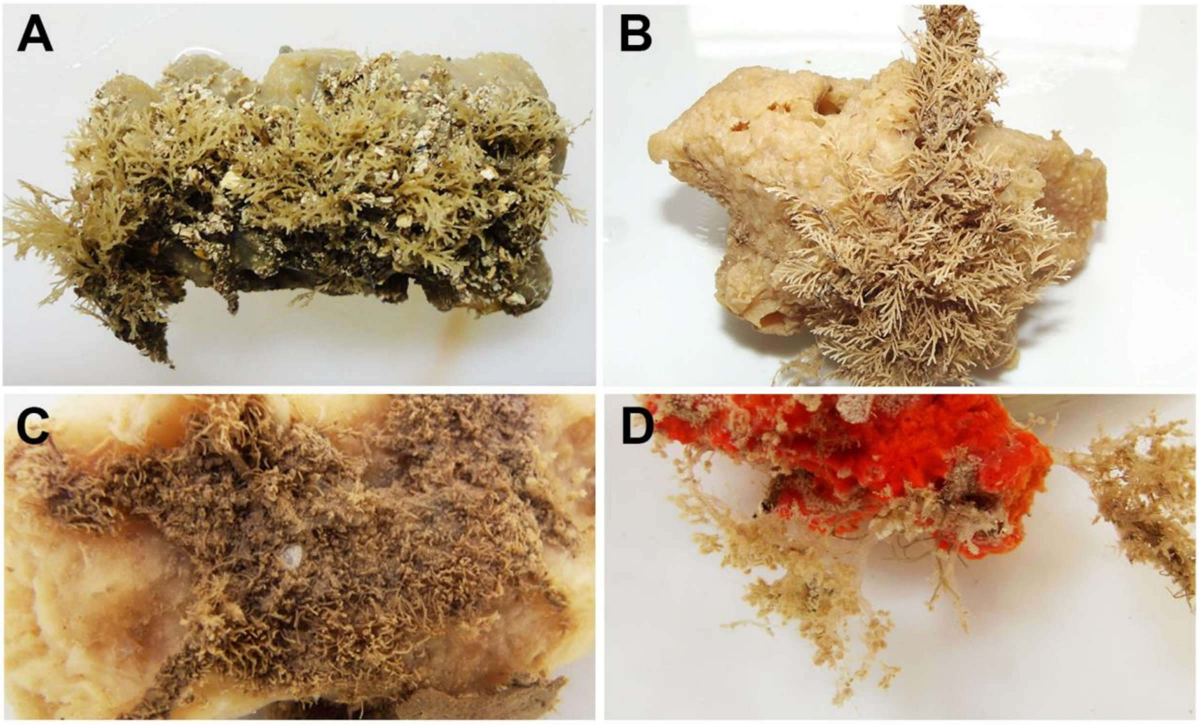

Fig. 7 Examples of bryozoan-sponge association in Pontas de Pedra, Pernambuco, Northeastern Brazil. The erect bryozoan *Licornia* sp. growing on the sponges *Desmapsamma anchorata* (A) and *Tedania ignis* (B); C, the encrusting bryozoan *Nolella stipata* encrusting majority of surface of the sponge *Tedania ignis*; D, the non-indigenous bryozoan *Amathia verticillata* growing on the sponge *Tedania ignis*.

Table 4 Abundance of bryozoans on per each sampled sponges (in bold). It was attributed to bryozoans (+) when found between 1–4 colonies, (++) 5–9 colonies, and (+++) ≥10 colonies.

	2014				**2015**												**2016**	
	sep	**oct**	**Nov**	**dec**	**jan**	**fev**	**mar**	**apr**	**may**	**jun**	**jul**	**aug**	**sep**	**oct**	**nov**	**dec**	**jan**	**Fev**
Amphimedon compressa																		
Licornia sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Nolella stipata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Thalamoporella floridana	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphimedon viridis																		
Amathia distans	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Amathia vidovici	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Nolella stipata	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Savignyella lafontii	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Desmapsamma anchorata																		
Amathia distans	-	-	-	-	-	-	-	++	-	-	+	-	-	+++	-	+	-	+++
Amathia vidovici	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
Catenicella uberrima	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Caulibugula dendograpta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++
Licornia sp.	+++	-	-	+	+	++	-	+	+	+	+	+	+	+	+	+	-	+++
Nolella stipata	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Savignyella lafontii	+++	+	+	-	-	++	-	-	-	-	-	-	+	+	+	-	-	-
Synnotum aegyptiacum	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+++
Thalamoporella floridana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-

Table 4 (Continued).

	2014				2015												2016	
	sep	**oct**	**Nov**	**dec**	**jan**	**fev**	**mar**	**apr**	**may**	**jun**	**jul**	**aug**	**sep**	**oct**	**nov**	**dec**	**jan**	**Fev**
Dysidea etheria																		
Amathia distans	-	-	-	-	+++	-	-	-	-	+	++	+++	-	+	-	-	-	+
Amathia vidovici	-	-	-	+	+++	-	-	-	-	-	+	-	+	-	-	-	-	-
Caulibugula dendograpta	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Licornia sp.	++	-	-	++	+	-	-	-	-	++	-	+	-	-	-	-	-	-
Nolella stipata	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-
Savignyella lafontii	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	+	-
Synnotum aegyptiacum	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Haliclona implexiformis																		
Amathia distans	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amathia vidovici	++	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nolella stipata	+	-	+	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-
Savignyella lafontii	-	-	++	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Synnotum aegyptiacum	+++	-	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-
Tedania ignis																		
Amathia distans	-	+	-	-	-	-	+	-	-	+++	-	-	-	-	-	-	++	-
Amathia verticillata	-	-	-	-	-	-	-	-	-	-	++	+	+++	-	-	+++	-	+++
Amathia vidovici	+++	+	-	-	-	+++	+++	+++	+	+++	-	-	-	+	-	+	++	-
Beania klugei	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caulibugula dendograpta	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Licornia sp.	+++	-	-	+	-	+++	+	-	-	-	-	-	-	-	-	-	+	-
Nolella stipata	+++	-	+	-	-	+++	+++	+++	-	+++	-	-	+	+	-	+++	+++	-
Savignyella lafontii	+++	-	-	-	-	+++	++	+	-	-	-	-	-	-	-	+++	+	-
Synnotum aegyptiacum	++	-	-	-	-	+	+++	+	-	+++	-	-	-	-	-	+++	-	-

The MDS plot for the Sorensen similarity analysis using the substratum factor (sponge species) shows a separation between *Ap*. *compressa* with the bryozoan *Th*. *floridana* from other groups. Three other groups were recognized with similarity among itself, the first with bryozoans found on *De*. *anchorata*, the second with *Te*. *ignis*, and finally with the sponge *H*. *implexiformis* (Fig. 8). The MDS plot for months suggest random temporal variation in the occurrence of bryozoans on sponges (Fig. 9). The positions of sponges demonstrate few differences between groups, in MDS plot for position factor (Fig. 10).

ANOSIM (Global R=0.305) indicated divergence between the bryozoan fauna on sponges *De*. *anchorata* and *H*. *implexiformis* (R=0.574), *De*. *anchorata* and *Ap*. *viridis* (R=0.473), and *Te*. *ignis* from *De*. *ancoratha* (R=0.463). ANOSIM also indicated similarity between *De*. *anchorata* and *Dy*. *etheria* (R=0.029), and *Te*. *ignis* from *H*. *implexiformis* (R=0.080).

The Cluster for the Bray-Curtis similarity (Fig. 11) with total samples, grouped the sponges *De*. *anchorata* and *Dy*. *etheria*, with *Te*. *ignis* with exclusive *At*. *verticillata* and *B*. *klugei* bryozoans. They share the presence of *Licornia* sp. and *Cl*. *dendograpta* (Tab. 4). Other group was formed by *Ap*. *viridis* and *H*. *implexiformis* with absent of the bryozoan *Licornia* sp and *Cl*. *dendograpta*. The sponge *Ap*. *compressa* did not form grouping because it not shares the presence of the bryozoans *At*. *distans* and *At*. *vidovici* with others sponges.

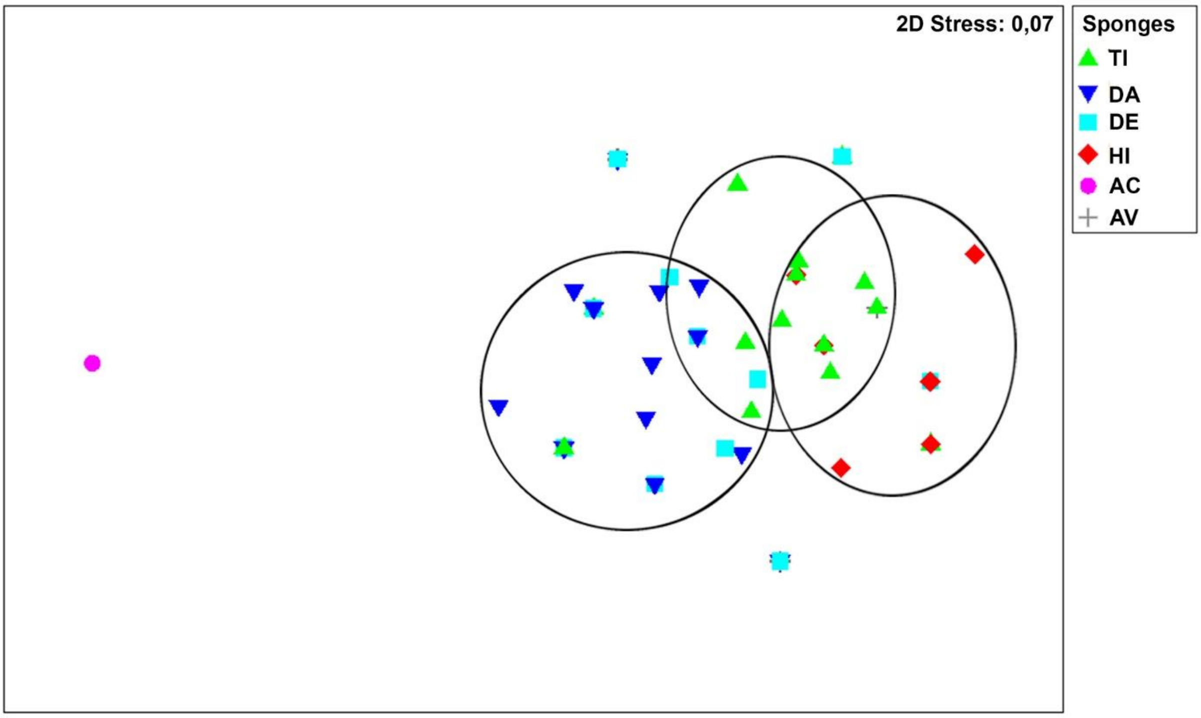

Fig. 8 Multidimensional scaling ordination plots for the Sorensen similarity for the sponges factor in occurrence of bryozoans, circles showing the groups of sponges. Legends: TI = *Tedania ignis*; DA = *Desmapsamma anchorata*; DE = *Dysidea etheria*; HI = *Haliclona implexiformis*; AC = *Amphimedon compressa*; AV = *Amphimedon viridis*.

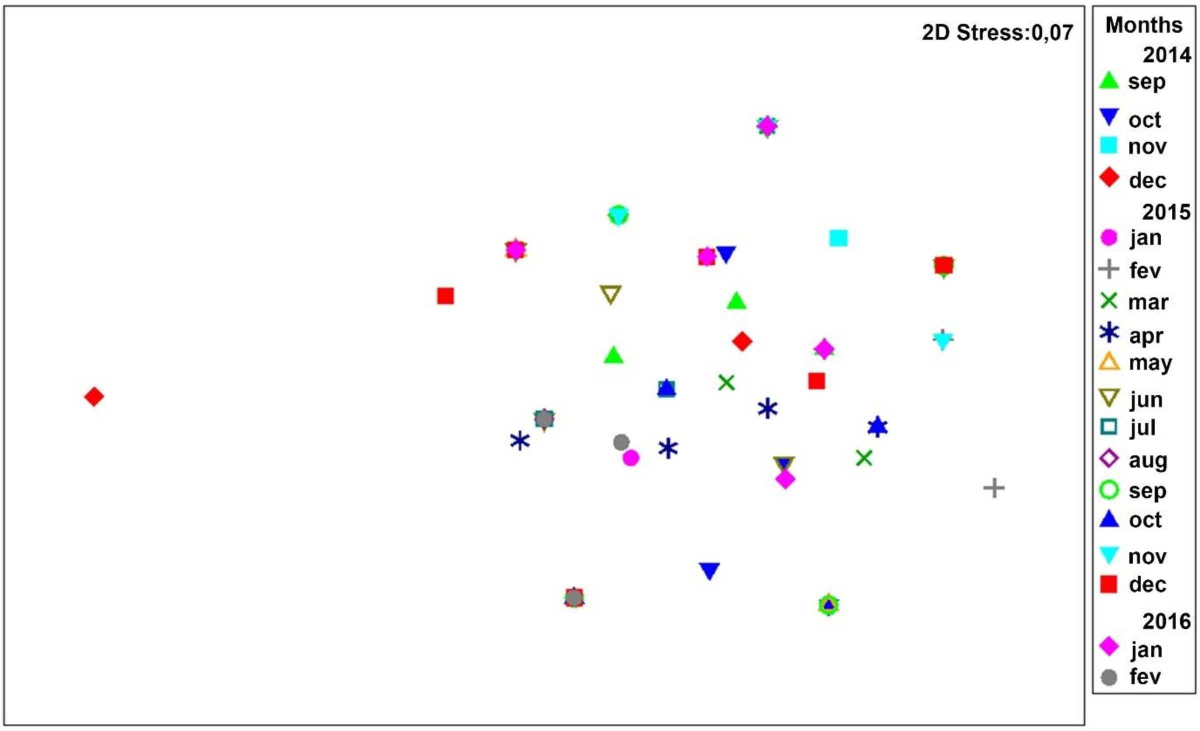

Fig. 9 Multidimensional scaling ordination plots for the Sorensen similarity for the month factor in occurrence of bryozoans.

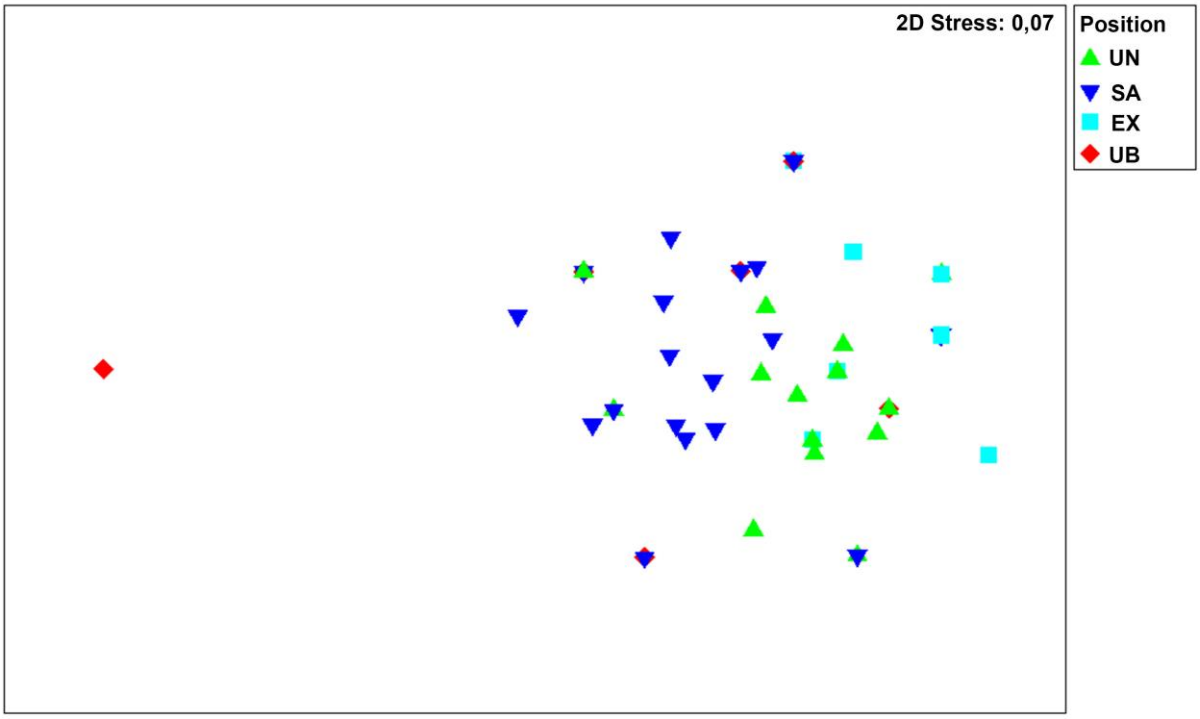

Fig. 10 Multidimensional scaling ordination plots for the Sorensen similarity for the position factor of sponges in occurrence of bryozoans, in beachrock at Pontas de Pedra, Pernambuco, Northeastern Brazil. Legends: UN = sponges under beachrocks, *Tedania ignis*; SA = sponges occurring between sand and beachrocks, *Desmapsamma anchorata* and *Dysidea etheria*; EX = sponge found on beachrocks exposed to sunlight, *Haliclona implexiformis*; UB = sponges found under beachrocks in a different position than *Te*. *ignis*, *Amphimedon compressa* and *Amphimedon viridis*.

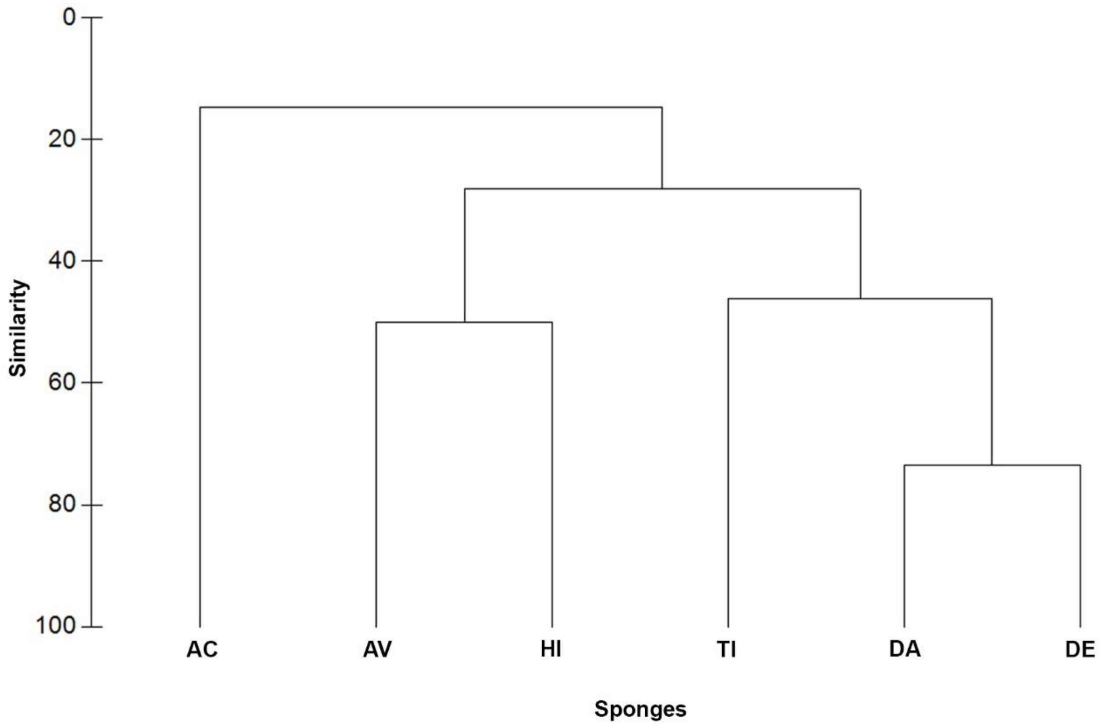

Fig. 11 Cluster for Bray-Curtis similarity for the occurrence of bryozoans on sponges. Legends: TI = *Tedania ignis*; DA = *Desmapsamma anchorata*; DE = *Dysidea etheria*; HI = *Haliclona implexiformis*; AC = *Amphimedon compressa*; AV = *Amphimedon viridis*.

Discussion

Substrata preferences

The frequency of occurrence of bryozoans on sponges showed significant differences among sponge species. The richness and abundance of bryozoans were high on sponges *De. anchorata* and *Te. ignis*, which have smooth and velvety surface, and smooth, tuberculate or villous surface, respectively. Smooth surface is also characteristic of *Ap. compressa* and *Ap. viridis* sponges, which had the lowest diversity and quantity of bryozoan colonies. Klitgaard (1995) found a high diversity of bryozoans covering sponges with a hispid surface, and suggest that these sponges may provide on soft bottoms a hard substratum for other invertebrates. In the present study, the sponges surface was not a representative factor in the occurrence of bryozoans, with no host-specific species.

A high similarity was found in cluster ordination between bryozoan found on *De. anchorata* and *Dy. etheria*, the last one with typical conulose surface. These were reinforced with ANOSIM analysis. Different surface morphologies presented by sponges were not inhibitor for presence of species of bryozoans.

According to Cook (1985), some bryozoans are not capable of choosing their substrata while other species show preference for certain substrata. In this study, all bryozoans found on sponges are reported as generalist (Vieira et al., 2008; Fehlauer-Ale et al., 2011; Vieira et al., 2013; Ramalho et al., 2014), and they are randomly found on different substrata. Sponges in study area occupied most of substratum available in intertidal zone, thus they may provide suitable substrata and attachment surface for the bryozoans.

Bryozoan taxa were mainly represented by erect species, as reported by Klitgaard (1995), who recorded 20 erect species (64.5 %), and only 11 encrusting species (35.5 %) on sponges. This might be related with the presence of anchoring kenozooids structures, found in erect bryozoans.

Some bryozoans require a substratum that provides stability for settlement, and many species also prefer substrata with a smooth and hydrophobic surface (Maki et al., 1989). It could explain the lowest number of laminar colonies found on sponges. The hydrophilic and different morphologies of surface presented by sponges may not be favorable to some bryozoans with laminar colonies. Additionally, anchoring kenozooid structures are absent almost encrusting bryozoans, which may turn sponges an unfavorable surface to encrusting species, despite the occurrence of *Th. floridana* and *N. stipata* on sponges. On the other hand, the majority of erect species have anchoring kenozooids (rhizoids), which is considered an advantage of the bryozoan to growth on adverse condition of substrata (Vieira & Stampar, 2014). These kenozooids may allow the bryozoan to grow on the sponge and anchoring the colony and zooids to feed with less interference of sediment over the sponge, also preventing the direct contact of the bryozoan and the sponge chemical compounds.

Winston (1982) described that erect bryozoans was found attached directly to the undersurfaces of beachrock ledges while other forms encrusted or attached to co-occurring hydroids and algae. In present study, bryozoans were more common on sponges where occurs in photonegative microhabits. A low number of species were found on *H. implexiformis* occurring in areas exposed to sunlight. Thus, different microhabitats could influence the occurrence of bryozoans, such as in small reentrances or below the beachrocks, with no direct exposition of the sunlight.

The bryozoan *Licornia* sp. was frequent on sponges *Dy. etheria* and *De. anchorata* while the bryozoans *At. vidovici* and *N. stipata* were considered abundant on *Te. ignis* and less frequent on *Dy. etheria* and *De. anchorata*. The frequency of these bryozoans could be related with the occurrence area of sponges in Pontas de Pedra. The sand microhabitat may not be favorable to bryozoans *At. vidovici* and *N. stipata*, while *Licornia* sp. could be more adapted to this environmental.

Sponges toxicity

The secondary metabolites present in *Ap. compressa* and *Ap. viridis* probably inhibited the settlement and growth of some bryozoan species, which explains the low diversity of epibenthic bryozoans growing on these sponges. This ability has been seen in other sponges as *Crambe crambe* (Schmidt, 1862) that was capable of inhibiting settlement of *Bugula neritina* (Linnaeus, 1758) larvae (Beccero et al., 1997).

The amphitoxin present in *Ap. compressa* is sufficient to provide an effective chemical defense, in natural concentration levels effectively deterred feeding of a generalist predatory Caribbean reef fish (Albrysio et al., 1995) and also its purified amphitoxin inhibited bacterial attachment at natural concentrations (Kelly et al., 2003). *Amphimedon viridis*, however, has a halitoxin complex with moderate lethal activity in animals (Berlinck et al., 1996), and it is also confirmed high lethal activity of an actinulae settled experiment of *Zyzzyzus warreni* Calder, 1988, where *Ap. viridis* was one of the most lethal, i.e. 100% of actinulae died during the first 20 min of exposure (Campos et al., 2012).

The secondary metabolites of *Te. ignis* and *Dy. etheria*, however, did not affect the occurrence of bryozoans. Known as 'fire sponge', *Te. ignis* is recognized by the fact that many people when handling the sponge acquire a dermal inflammation (De Laubenfels & Hindle, 1950; Muricy & Hajdu, 2006). It has a potent cytotoxic designated tedanolide which showed cytotoxicity and tumor inhibition (Schmitz et al., 1984). *Tedania ignis* showed fouling activity, it was elicited settlement and metamorphosis in more than 50% of the actinulae within the first 60 minutes of exposure (Campos et al., 2012). However, studies carried in Caribbean Sea show that *Te. ignis* are vulnerable to predation (Waddell & Pawlik, 2000; Wulff, 2010). Evidences demonstrated that chemical defenses are an important antipredatory strategy of Caribbean sponges such as *Dy. etheria* that shows a low feeding behavior by a sea stars (Waddell & Pawlik, 2000).

As concluded by Puce et al. (2005) sponges could protects hydroids colonies from predation by nudibranchs and from overgrowth by other benthic organisms. Thus, the secondary metabolites in some sponges did not work as antifouling and they could offer safe substrata for associated orgarnisms, since it could keep away any potential predators, including nudibranchs.

Rittschof & Costlow (1989) suggested the settlement of bryozoan larvae may be influenciate by the chemistry and wettability of substrata. The presence of the encrusting bryozoans *N. stipata Th. floridana* on toxic sponges indicate the resistence of the larvae against these chemical compounds. Thus, we suggest more studies to verify the capability of bryozoan larvae to settle and grown on *Ap. compressa* and *Ap. viridis*.

Temporal variations

The occurrence of bryozoans on sponges was random during 18 months of sampling. A comparing analysis indicated no seasonal variation (rainy and dry season) between macrofauna inhabits the calcareous sponge *Paraleucilla magna* Klautau, Monteiro & Borojevic, 2004 (Pádua et al., 2012).

The embryos found in *Licornia* sp. could reveal that species reproduction occur along the year and with no influence of rainy season, while the colonies of *Sa. lafontii* were not enough to establish the species reproduction season. Despite the absence of embryos on *At. verticillata*, we have found young colonies in two months after rainy months, which decreasing of salinity, possibly due the preference of this species for low salinity (Vieira et al., 2014). Winston (1982) compared seasonal occurrence and presence of reproductive colonies of species of bryozoans, in Florida, and they could varieted among species. In general, the bryozoan embryos found at Pontas de Pedra may not reveal the real breeding of these bryozoans, because only bryozoans associated to sponges was included in this study.

These findings, however, indicate that these bryozoans may complete their life cycle after the larval settlement on sponges.

Geographical distribution

All bryozoan species found in this study have already been reported for Brazilian coast. The most frequent species of bryozoans growing on sponges, e.g. *At. distans*, *At. vidovici*, *Licornia* sp., *N. stipata* and *Sa. lafontii*, are considered generalist species reported in other regions from Brazilian coast (Vieira et al., 2008; Fehlauer-Ale et al., 2011; Vieira et al., 2013; Ramalho et al., 2014). The bryozoans *At. vidovici*, *B. klugei*, *Ct. uberrima* and *N. stipata* are widespread in tropical to subtropical waters (Vieira et al., 2012; Ramalho et al., 2014; Vieira et al., 2014), thus the capacity of these bryozoans growing on different substrata, including sponges, may be favorable for the dispersion of these species.

Two ctenostomatous bryozoans often co-occur on sponges, *At. distans* and *At. vidovici*. *Amathia distans* are reported from Brazil to Florida on different substrata, such as algae, bryozoans, and anthropogenic surfaces (Fehlauer-Ale et al., 2011). In the present study, it was considered frequent on both *De. anchorata* and *Dy. etheria*. Colonies of *At. distans* were abundant on sponges, which demonstrate there are no substratum preferences by this bryozoan. With broader distribution, the *At. vidovici* species are a well distributed bryozoan from Atlantic Ocean, being known from Adriatic Sea (Hayward & McKinney, 2002), Belize (Winston, 2004), Florida (Winston, 1982), Puerto Rico (Osburn, 1940) and Brazil (Vieira et al., 2008; Migotto et al., 2011). During sampling, it was abundant occurring year round on *Te. ignis* surface.

The third *Amathia* species found on sponges, *At. verticillata* is widely reported as an exotic species, recorded from different areas, such as United States, Australia and Seychelles (Amat & Tempera, 2009). It is commonly found in ports and harbours in warm to temperate seas, including Brazil (Abdel-Salam & Ramadan, 2008; Vieira et al., 2014). Galil & Gevili (2014) suggest *At. verticillata* as native from Caribbean Sea where occur in natural environments, but they also suggest molecular studies may provide further evidence as to its origin and history of invasion. The species is considered common in natural and artificial substrata from Florida (USA) to south of Brazil (Winston, 1982; Migotto et al., 2011; Vieira et al, 2014). In Brazil, *At. verticillata* was reported from Rio Grande do Norte (Farrapeira, 2011), Santa Catarina (Müller, 1860; Bouzon et al., 2012) and São Paulo States (Fehlauer-Ale et al., 2011; Migotto et al., 2011; Marques et al., 2013; Vieira et al., 2014). During the present study, *At. verticillata* was found only on *Te. ignis* between July/2015 and February/2016. This period is characterized by the end of the rainy season in the study area, when young colonies of *At*. *verticillata* were found. Despite the presence of large colonies of *At. verticillata* during a short period in the summer in Azores (Amat & Tempera, 2009), no large colonies were observed in present study, even the temperature being considered favorable for this species (26.6°C to 27.3°C).

Abdel-Salam & Ramadan (2008) reported colonies of *At*. *verticillata* partly overgrowing other sessile organisms at the Eastern Harbour of Alexandria. Probably, the specimens of *At*. *verticillata* in the study area prevent the settlement of other bryozoan species on *Te*. *ignis* sponge, which explains the exclusive occurrence of *At*. *verticillata* on *Te*. *ignis*. *Amathia verticillata* produces secondary metabolites that may have influence in the settlement of other organisms (Amat & Tempera, 2009), which reinforce our hypothesis.

Nolella stipata is a cosmopolitan bryozoan, but it may comprise a species complex (Vieira et al., 2014). This bryozoan was previously recorded with entire year in cryptic habits in Florida, USA (Winston, 1982). It was reported from Pernambuco, Alagoas, Espírito Santo and São Paulo States from Brazil (Vieira et al., 2014), and it was the most abundant bryozoan species during this study, also occurring in all sponges.

Licornia sp. is a dominant bryozoan species from Pontas de Pedra. This species was previously reported from Western Atlantic as *Licornia diadema* (Busk, 1852) (see Vieira et al., 2013), now considered a species complex. It occurs more frequently on *De*. *anchorata* and *Dy*. *etheria* sponges, which presents smooth and conulose surface, respectively. The high frequency of *Licornia* sp. on these sponges may be due the collection site, restricted to the area between sand and beachrocks. Apparently, this species has torelance to sediment deposition since living colonies were found completely coved by sediment.

The bryozoan *B*. *klugei* was considered a common epibiont in Rio de Janeiro State, Brazil, growing on algae, hydrozoans and other bryozoans (Ramalho et al., 2008). It did not seem to prefer any particular type of substratum, and may also occur on bivalves and barnacles (Lira et al., 2010). During the present study, however, it was found only on sponge *Te*. *ignis*, suggesting this bryozoan may prefer calcareous substrata then soft substrata as sponges. Currently, this species is widely reported in warm-waters, and in Brazil is is known from Bahia, Pernambuco, Rio de Janeiro and São Paulo States (Vieira et al., 2008; Ramalho et al., 2008; Almeida et al., 2015).

The species *Caulibugula dendograpta* was reported from São Paulo State, Brazil (Vieira et al., 2008), and studies about its occurrence and substrata preference are scarce. The species was reported from Santos Bay, Brazil, associated with sponges, brachyuran and shells from 20 meters depth (Marcus, 1938). This bryozoan was found on sponges *De*. *anchorata*, *Dy*. *etheria* and *Te*. *ignis* during the summer months in Pontas de Pedra.

Catenicella uberrima is a well-known species, considered cosmopolitan from warm water (Winston, 1982). In Brazil, it was reported from Rio de Janeiro (Ramalho et al., 2014), Alagoas (Vieira et al., 2007) and São Paulo (Migotto et al., 2011; Vieira et al., 2012). Only a single colony of *Ct*. *uberrima* was found on *Te*. *ignis*. Ramalho et al. (2014) reported the occurrence of this species on artificial substrata and rocks, while it was recorded in association with the bryozoan *Vasignyella ovicellata* Vieira, Gordon & Correia, 2007, in Alagoas State, Brazil (Vieira et al., 2007).

Small delicate colonies of the bryozoan *Sa*. *lafontii* were considered frequent on *De*. *anchorata* and *Te*. *ignis* during dry seasons at Pontas de Pedra. It is a worldwide distributed species from warm and warm-temperate shallow waters (Cook, 1985). Winston (1982) recorded this species from Florida on different substrata, such as algae, sponges and other bryozoans. In Brazil, *Sa*. *lafontii* was reported for Alagoas (Vieira et al., 2007), Bahia (Almeida et al., 2015) and São Paulo States (Rocha, 1995; Migotto et al., 2011; Marques et al., 2013).

Synnotum aegyptiacum is widely distributed in warm waters, occurring on hydroids, shells and beachrocks in Florida (Winston, 1982). It has records in Brazil for Fernando de Noronha Archipelago, Alagoas, Bahia, Espírito Santo and São Paulo States (Vieira et al., 2008; Almeida et al., 2015), and aparrently it has no preference for any kind of substratum. The species was more frequent on *H*. *implexiformis* and *Te*. *ignis*.

In Brazil, *Thalamoporella floridana* was recently reported for Alagoas State (Vieira et al., 2016), being first reported from São Paulo State, Brazil (Vieira et al., 2008). This especies was recorded along the year from Florida, growing on hydroids and algae (Winston, 1982), and from Gulf of Mexico, on algae and floating substrata. Colonies of *Th*. *floridana* were found only one time on the sponges *Ap*. *compressa* and *De*. *anchorata*.

Conclusion

In Pontas de Pedra, the bryozoans growing on sponges are considered generalist, thus they do not have preferences to any surfaces of sponges. The substratum where sponges were found, however, is considered important to bryozoan settlement. The presence of erect colonies, often with rhizoidal kenozooids, may be related with their capacity to anchoring the colony on this sort of substratum, being an advantage to growth with less interference from sediment deposition, preventing direct contact with the sponge and their chemical compounds. On the other hand, the secundary metabolites present in sponges *Ap*. *compressa* and *Ap*. *viridis* may inhibit some bryozoans. The sponges *Te*. *ignis*, *De*. *anchorata* and *Dy*. *etheria* were a suitable substratum for bryozoans. The bryozoan *Amathia verticillata* may prevent the settlement of other bryozoan species on *Te*. *ignis* sponge. The temporal variation does not affect the occurrence of bryozoans on sponges.

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5 CONSIDERAÇÕES FINAIS

- As diferentes superficies apresentadas pelas seis espécies de esponjas estudadas não foram um fator determinante na ocorrência das espécies de briozoários. A presença de estruturas adaptivas foram importantes nesta associação, pois impediam um contato direto das colônias na superfície da esponja;
- Os briozoários encontrados nas esponjas são espécies generalistas e sua distribuição sobre as esponjas tente a ser aleatória. Sendo que, a presença de um maior número de espécies eretas pode estar relacionada as características ambientais da área de estudo;
- A composição das esponjas *Amphimedon compressa* e *Amphimedon viridis* pode ter inibido a presença de briozoários. As esponjas *Tedania ignis*, *Desmapsamma anchorata* e *Dysidea etheria* apresentaram uma maior abundancia e riqueza de briozoários, essas esponjas são um substrato comum para briozoários na área de estudo;
- A ocorrência das espécies de briozoários nas esponjas durante os meses de coleta foi aleatório. As colônias das espécies *Licornia* sp., *Savignyella lafontii* e *Amathia verticillata* encontradas com embriões não revelam nenhum padrão temporal de reprodução dessas espécies, mas pode indicar que estas espécies são capazes de concluir seu ciclo reprodutivo nas esponjas;
- Sete briozoários, *Amathia distans*, *Amathia verticillata*, *Amathia vidovici*, *Catenicella uberrima*, *Caulibugula dendrograpta*, *Savignyella lafontii* e *Thalamoporella floridana*, estão sendo reportados pela primeira vez para o Estado de Pernambuco.

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