ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 10, Issue, 04, pp. 34943-34951, April, 2020

RESEARCH ARTICLE OPEN ACCESS

SPECIES RICHNESS OF PYCNOGONIDA AND ECHINODERMATA ASSOCIATED WITH THE REEF ECOSYSTEMS OF MORRO DE SÃO PAULO ON TINHARÉ ISLAND IN NORTHEASTERN BRAZIL

Jéssica Prata*[1,2,3], Rudá Amorim Lucena[1,2], Silvio Felipe Barbosa Lima[2,4], J. Weverton S. Souza[5] and Martin Lindsey Christoffersen[1,2,6]

[1]Universidade Federal da Paraíba, Centro de Ciências Exatas e da Natureza, Departamento de Sistemática e Ecologia, Laboratório de Invertebrados Paulo Young, Cidade Universitária, João Pessoa, Paraíba, 58051-900, Brazil; [2]Universidade Federal da Paraíba, Centro de Ciências Exatas e da Natureza, Departamento de Sistemática e Ecologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Cidade Universitária, João Pessoa, Paraíba, 58051-900, Brazil; [3]Universidade Federal da Paraíba – Campus II, Centro de Ciências Agrárias, Departamento de Ciências Biológicas, Cidade Universitária, Areia, Paraíba, 58397-000, Brasil; [4]Universidade Federal de Campina Grande, Centro de Formação de Professores, Unidade Acadêmica de Ciências Exatas e da Natureza, Casas Populares, Cajazeiras, Paraíba, 58900-000, Brazil; [5]Universidade Estadual de Campinas, Instituto de Biologia, Programa de Pós-Graduação em Ecologia, Avenida Bertrand Russel, Cidade Universitária Zeferino Vaz - Barão Geraldo, Campinas, São Paulo, 13083-865, Brazil; [6]Universidade Federal da Paraíba, Centro de Ciências Exatas e da Natureza, Departamento de Sistemática e Ecologia, Laboratório de Biodiversidade de Invertebrados Não-Insetos, Cidade Universitária, João Pessoa, Paraíba, 58051-900, Brazil

ARTICLE INFO

ArticleHistory:
Received 03rd January, 2020
Received in revised form
11th February, 2020
Accepted 26th March, 2020
Published online 29th April, 2020

KeyWords:

Ammotheidae, Ophiuroidea, Asteroidea, Echinoidea, Holothuroidea, Southwestern Atlantic, Tinharé and Boipeba Archipelago, intertidal zone, shallow waters.

***Corresponding author:* JéssicaPrata,**

ABSTRACT

Invertebrates associated with the reef ecosystems of Morro de São Paulo on Tinharé Island in the state of Bahia, northeastern Brazil were studied from samples collected in January and September 2015. A total of 119 individuals belonging to 26 species and 16 families were identified among Pycnogonida and Echinodermata. The families Ophiactidae and Ophiodermatidae (Echinodermata) were the most representative taxa. The most abundant families were Ophiactidae and Amphiuridae (Echinodermata) with 76 individuals. The pycnogonids recorded for Morro de São Paulo were *Achelia sawaya*, *Ammothella spinifera* and *Tanystylum isabellae*, all found on algae. Algae constitute a good habitat for sea spiders and small ophiuroids in shallow waters. These numbers evidence how little we know about coastal marine invertebrate fauna in Brazil and indicate the need for further sampling, especially in the study area.

Citation: ***Jéssica Prata, Rudá Amorim Lucena, Silvio Felipe Barbosa Lima, J. Weverton S. Souza and Martin Lindsey Christoffersen.*** **2020.** "Species richness of Pycnogonida and Echinodermata associated with the reef ecosystems of Morro de São Paulo on Tinharé Island in Northeastern Brazil*"*, *International Journal of Development Research*, 10, (04), 34943-34951.

INTRODUCTION

Brazil has one of the largest marine zones of the world, which is formed by contiguous ecosystems with high ecological complexity (MMA, 2010). The coast between French Guiana (about: 5° N) (Moura *et al*., 2016) and the southeastern region of Brazil (20° S) (Mazzei *et al*., 2016) comprises important tropical marine ecoregions in the South Atlantic Ocean due to the occurrence of extensive, complex reef ecosystems with considerable biodiversity (MMA, 2002, 2010; Leão *et al*., 2003, 2016; Amaral and Jablonski, 2005; Mazzei *et al*., 2016; Moura *et al*., 2016). The northeastern coast of Brazil is highly favorable to the formation of reef ecosystems, which are distributed over about three thousand kilometers between the states of Maranhão and Bahia (Amaral and Jablonski, 2005; MMA, 2002, 2010). The coast of the state of Bahia stands out for having the largest, richest, most exuberant and complex

reef ecosystems of the South Atlantic (Costa Jr. *et al*., 2000; Leão *et al*., 2003, 2008a, 2016; Mazzei *et al*., 2016; Dutra *et al*., 2005; Mazzei *et al*., 2016). Despite the extreme biological and ecological importance of the region, the fauna associated with the reef ecosystems of Bahia still needs to be inventoried properly, especially with regards to benthic invertebrates. Cnidarians in the reef ecosystems off the coast of Bahia are among the most studied invertebrates (Hetzel and Castro, 1994; Costa Jr. *et al*., 2000; Leão *et al*., 2003, 2008a, b; Castro *et al*., 2005a, b; Kikuchi *et al*., 2008; Cruz *et al*., 2009; Krug *et al*., 2012; Miranda *et al*., 2013; Silva *et al*., 2013; Vasconcellos *et al*., 2018; Freitas *et al*., 2019). In contrast, the biodiversity of other groups of marine invertebrates associated with the reef ecosystems of this region have been insufficiently sampled and studied. The main surveys on invertebrate richness associated with the reef ecosystems of Bahia addressed echinoderms (Albuquerque and Guille, 1991), crustaceans (Young and Serejo, 2005a, b), polychaetes (Paiva, 2005a, b), mollusks (Absalão, 2005a, b) and pycnogonids (Lucena and Christoffersen, 2017) of the Abrolhos Archipelago. Lima *et al*. (2019) also inventoried benthic mollusks associated with the reef ecosystems of Morro de São Paulo on Tinharé Island. The Tinharé and Boipeba Archipelago is located in the central-southern portion of the state of Bahia and is surrounded by a large quantity of non-continuous shallow reef ecosystems (Kikuchi *et al*., 2008; Leão*et al*., 2016; Elliff and Kikuchi, 2017), mostly fringing reefs with truncated, irregular tops that become exposed at low tide, forming channels and tide pools (Kikuchi *et al*., 2008; Elliff and Kikuchi, 2017). Tinharé and Boipeba are the largest islands of the archipelago and Morro de São Paulo is one of the largest areas on Tinharé Island (Elliff and Kikuchi, 2017) with reef ecosystems and a number of associated benthic invertebrates (Kikuchi *et al*. 2008). However, such reef ecosystems are extremely vulnerable to human actions (Loiola *et al*., 2014; Elliff and Kikuchi, 2017; Rhormens *et al*., 2017; Lima *et al*., 2019). The aim of the present study was to document the biodiversity of Pycnogonida and Echinoidermata of the reef ecosystems of Morro de São Paulo located on Tinharé Island in the state of Bahia, Brazil.

MATERIAL AND METHODS

Study area: Morro de São Paulo is located on Tinharé Island in the municipality of Cairu, state of Bahia, Brazil, and pertains to the Tinharé-Boipeba Environmental Preservation Area (13º22'56.0" S, 38º54'32.1" W) located between the mouth of Patos River and the Taperoá Channel (INEMA, 2016; Elliff and Kikuchi, 2017). The area is located in the Tropical Northwestern Marine Ecoregion (Spalding *et al*., 2007) and has an area of approximately 433 km^2 (Figure 1). The climate is tropical humid with periods of torrential rains and a high incidence of winds. Temperature ranges are small, with annual averages of 19.4 to 31.2°C. Mean yearly humidity ranges between 80 and 90%, and yearly precipitation is about 1700 mm (CEPLAC, 1975). The coastal environment of Morro de São Paulo has a large quantity of fringing reefs that become exposed at low tide. The tops of these reefs have an irregular, truncated surface that forms tide pools (Kikuchi *et al*., 2008). The reefs extend for tens of meters and are close to the beach line, forming discontinuous structures in shallower regions (Lima *et al*., 2019).

Sampling, identification and analysis: The sampling of invertebrates associated with the reef ecosystems on the three beaches located in Morro de São Paulo was conducted in January and September 2015. All invertebrates were collected manually through active searches at different points of the First, Second and Third Beaches at low tide from the intertidal zone to shallow subtidal areas at a depth of about 1 m. Individuals were collected with a proportional collecting effort from hard (e.g., surface, underneath and crevices) and soft (e.g., sand and gravel) substrate habitats of the reef ecosystems for approximately three hours at each beach. Algae were collected manually at different points of the study area and invertebrates were subsequently separated from the algae. The samples were placed in labelled plastic bags and sorted at the *Laboratório de Invertebrados Paulo Young* (LIPY [Paulo Young Invertebrate Laboratory]), *Universidade Federal da Paraíba* (UFPB [Federal University of Paraíba]). The specimens were separated, anesthetized with menthol and preserved in 70% ethanol. The collections were performed with the authorization of the Biodiversity Information and Authorization System (SISBIO 43234-2). Individuals were photographed *in situ* and at the LIPY under a Leica MZ12.5 stereomicroscope and using a Canon Powershot A2000IS digital camera. The identification of pycnogonids was mainly based on Marcus (1940) and Müller and Krapp (2009) and the identification of echinoderms was based on Tommasi (1969a, b, 1970a, b), Hendler *et al*. (1995), Borges *et al*. (2002), Borges and Amaral (2005), Manso *et al*. (2008), Pawson *et al*. (2010), Benavides-Serrato *et al*. (2011), Borrero-Pérez *et al*. (2012) and Martins *et al*. (2018). All material analyzed is deposited and available for study at the *Coleção de Invertebrados Paulo Young* (CIPY [Paulo Young Invertebrate Collection]) of the *Departamento de Sistemática e Ecologia* (DSE [Department of Systematics and Ecology]) of UFPB in the city of João Pessoa, Paraíba, Brazil.

RESULTS

Three species of Pycnogonida and 23 species of Echinodermata were collected and examined (Table 1). The species were mainly associated with the algae *Halimeda opuntia* (Linnaeus) J.V. Lamouroux, 1816, *Sargassum polyceratium* Montagne, 1837, *Lithothamnium* sp., *Ulva lactuca* Linnaeus, 1753 and *Gracilaria caudata* J. Agardh, 1852 in the reef area. Six individuals of Pycnogonida Latreille, 1810 were collected, accounting for only 5% of the specimens sampled. All sea spiders were removed from algae and classified in the family Ammotheidae Dohrn, 1881 and the genera *Achelia* Hodge, 1864, *Ammothella* Verrill, 1900 and *Tanystylum* Miers, 1879 (Figure 2). *Achelia sawayai* Marcus, 1940 (Figure 2B−C) was the most abundant pycnogonid, with four individuals in the samplings. One hundred thirteen specimens of Echinodermata were analyzed, corresponding to 95% of the total number of individuals collected. Twenty-three echinoderms (Figures 3−5) belonging to four classes, 15 families and 18 genera were found at the study site (Table 1). Ophiuroidea Gray, 1840 was the class with the largest number of species (n = 13) (Figures 3 and 4A−C), corresponding to 56.5% of the total number of echinoderms collected, followed by Echinoidea Leske, 1778 (n = 5) (Figures 4E−F and 5A−C), Holothuroidea (n = 4) (Figures 5D−G) and Asteroidea de Blainville, 1830 (n = 1) (Figure 4D) (Figure 6). The families with the greatest species richness were: Ophiactidae (n = 3), Ophiodermatidae (n = 3), Amphiuridae (n = 2), Ophiocomidae (n = 2), Toxopneustidae (n = 2) and Holothuriidae (n = 2) (Figure 7). These families represented about 61% of the total number of echinoderms collected in the area.

Table 1. Species of Pycnogonida and Echinodermata recorded at Morro de São Paulo, Tinharé Island, Bahia, Brazil

Phylum	Class/Family	Species	Sps	Voucher
Arthropoda	Pycnogonida			
	Ammotheidae Dohrn, 1881	*Achelia sawayai* Marcus, 1940	04	UFPB.PYC–205
		Ammothella spinifera Cole, 1904	01	UFPB.PYC–191
		Tanystyllum isabellae Marcus, 1940	01	UFPB.PYC–175
Echinodermata	Ophiuroidea Gray, 1840			
	Amphiuridae Ljungman, 1867	*Amphipholis squamata* (Delle Chiaje, 1828)	19	UFPB.ECH–2233
		Amphiura kinbergi Ljungman, 1872	03	UFPB.ECH–2245
	Ophiothrichidae Ljungman, 1867	*Ophiothrix angulata* (Say, 1825)	02	UFPB.ECH–2234
	Ophiactidae Matsumoto, 1915	*Ophiactis brasiliensis* Manso, 1988	48	UFPB.ECH–2241
		Ophiactis lymani Ljungman, 1872	03	UFPB ECH–2275
		Ophiactis savignyi (Müller & Troschel, 1842)	03	UFPB.ECH–2238
	Ophionereididae Ljungman, 1867	*Ophionereis squamulosa* Koehler, 1914	03	UFPB.ECH–2243
	Ophiocomidae Ljungman, 1867	*Ophiocomella ophiactoides* (H.L. Clark, 1900)	04	UFPB.ECH–2242
		Ophiocoma echinata (Lamarck, 1816)	04	UFPB.ECH–2235
	Ophiodermatidae Ljungman, 1867	*Ophioderma appressa* (Say, 1825)	01	UFPB.ECH–2236
		Ophioderma cinerea Müller & Troschel, 1842	01	UFPB.ECH–2237
		Ophioderma brevicauda Lütken, 1856	02	UFPB.ECH–2232
	Ophiolepididae Ljungman, 1867	*Ophiolepis paucispina* (Say, 1825)	01	UFPB.ECH–2239
	Asteroidea de Blainville, 1830			
	Ophidiasteridae Verrill, 1870	*Linckia guildingi* Gray, 1840	02	UFPB.ECH–2244
	Echinoidea Leske, 1778			
	Cidaridae Gray, 1825	*Eucidaris tribuloides* (Lamarck, 1816)	01	UFPB.ECH–2267
	Diadematidae Gray, 1855	*Diadema antillarum* Philippi, 1845	01	UFPB.ECH–2268
	Toxopneustidae Troschel, 1872	*Lytechinus variegatus variegatus* (Lamarck, 1816)	01	UFPB.ECH–2269
		Tripneustes ventricosus (Lamarck, 1816)	01	UFPB.ECH–2270
	Echinometridae Gray, 1825	*Echinometra lucunter* (Linnaeus, 1758)	01	UFPB.ECH–2271
	Holothuroidea Selenka, 1867			
	Phyllophoridae Östergren, 1907	*Stolus cognatus* (Lampert, 1885)	01	UFPB.ECH–2273
	Chiridotidae Östergren, 1898	*Chiridota rotifera* (Pourtalès, 1851)	08	UFPB.ECH–2247
	Holothuriidae Ludwig, 1894	*Holothuria* (*Halodeima*) *grisea* Selenka, 1867	01	UFPB.ECH–2272
		Holothuria (*Thymiosycia*) *arenicola* Semper, 1868	02	UFPB.ECH–2246

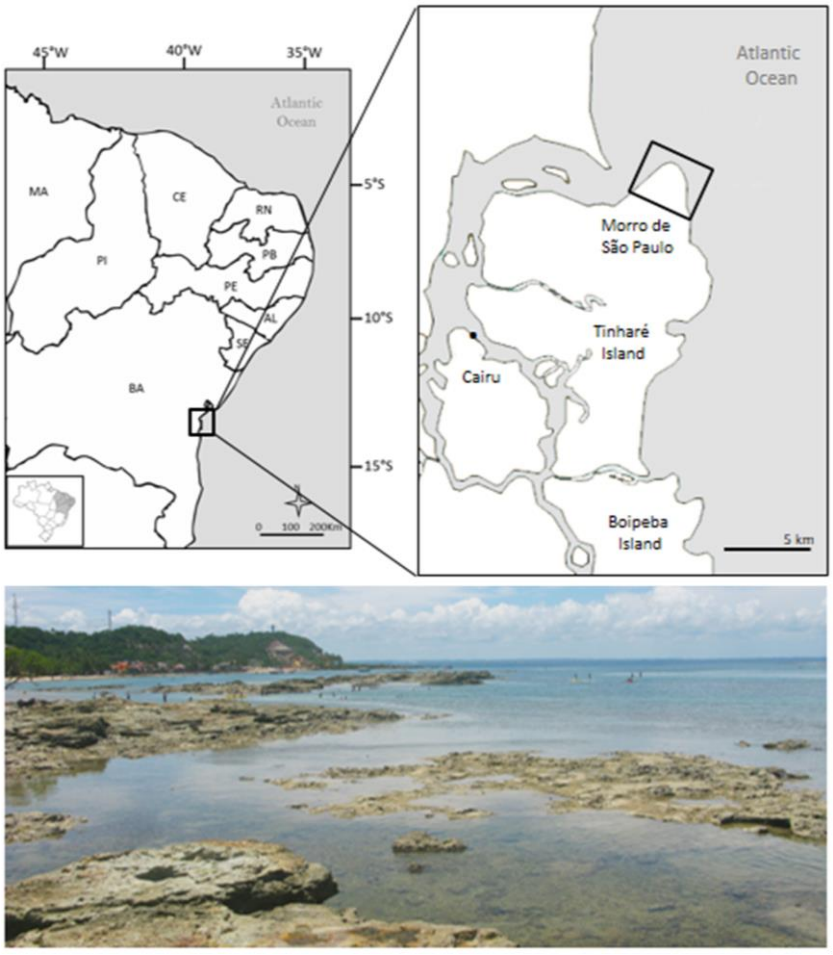

Figure 1. Location of study area on First, Second and Third Beaches, Morro de São Paulo, Tinharé Island, state of Bahia, northeastern Brazil

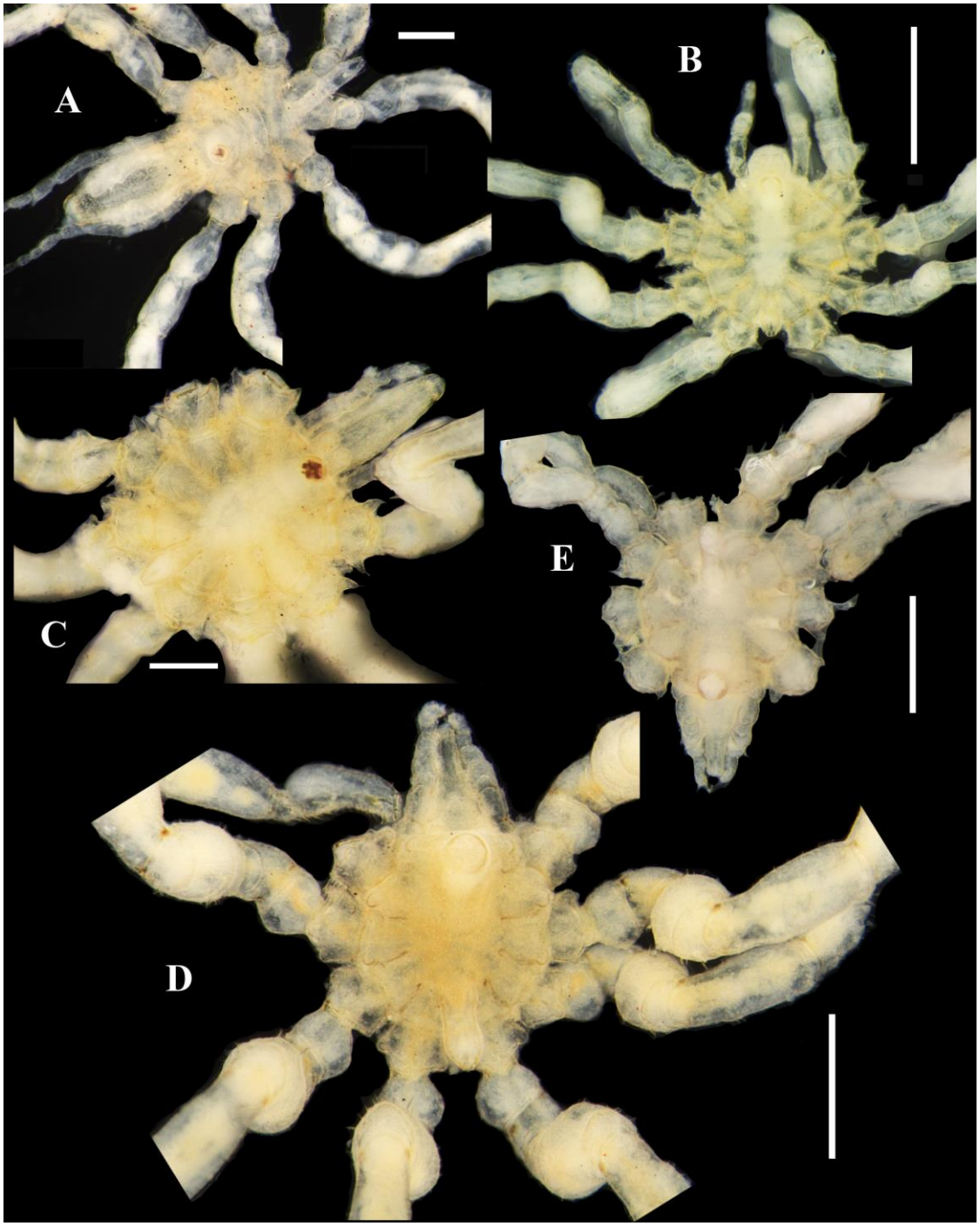

Figure 2. Pycnogonids associated with reef ecosystems in Morro de São Paulo: A. *Ammothella spinifera*; B–C. *Achelia sawayai*; D–E. *Tanystylum isabellae*. Scale bars: A–B and D. 1 mm, C and E. 500 µm

Echinoderms were found under rocks, buried in the sediment and between algae. The asteroid species *Linckia guildingi* Gray, 1840 was found among stones covered by algae (Figure 4D). The ophiuroids *Amphipholis squamata* (Delle Chiaje, 1828) (Figure 3A), *Ophiactis savignyi* (Müller & Troschel, 1842) (Figure 3F), *Ophiactis brasiliensis* Manso, 1988 (Figure 3D), *Ophiocomella ophiactoides* (H.L. Clark, 1900) (Figure 3H), *Ophionereis squamulosa* Koehler, 1914 (Figure 3G) and *Amphiura kinbergi* Ljungman, 1872 (Figure 3B) were associated with the phytal community in the reef area. The ophiuroids *Ophiothrix* (*Ophiothrix*) *angulata* (Say, 1825) (Figure 3C), *Ophiocoma echinata* (Lamarck, 1816) (Figure 4B−C), *Ophioderma appressa* (Say, 1825) (Figure 3J), *Ophioderma cinerea* Müller & Troschel, 1842 (Figure 3K), *Ophiolepis paucispina* (Say, 1825) (Figure 3I) and *Ophioderma brevicauda* Lütken, 1856 (Figure 4A) were found under stones or among groups of rocks. The echinoids *Eucidaris tribuloides* (Lamarck, 1816) (Figure 4E), *Echinometra lucunter* (Linnaeus, 1758) (Figure 5C), *Diadema antillarum* Philippi, 1845 (Figure 4F) and *Tripneustes ventricosus* (Lamarck, 1816) (Figure 5B) were found in cavities in rocks and less frequently buried in the substrate. *Lytechinus variegatus variegatus* (Lamarck, 1816) (Figure 5A) was found covered by sediment, gravel and algae, among other detritus. *Holothuria* (*Halodeima*) *grisea* Selenka, 1867 (Figure 5D) was the most commonly found species in the study area, with specimens usually hidden under rocks or less frequently buried in the substrate. Two young individuals of *Holothuria* (*Thymiosycia*) *arenicola* Semper, 1868 (Figure 5G) were found under stones. *Chiridota rotifera* (Figure 5F) was found buried in the sediment.

Figure 3. Echinoderms associated with reef ecosystems in Morro de São Paulo: A. *Amphipholis squamata*; B. *Amphiura kinbergi*; C. *Ophiothrix* (*Ophiothrix*) *angulata*; D. *Ophiactis brasiliensis*; E. *Ophiactis lymani*; F. *Ophiactis savignyi*; G. *Ophionereis squamulosa*; H. *Ophiocomella ophiactoides*; I. *Ophiolepis paucispina*; J. *Ophioderma appressa*; K. *Ophioderma cinerea*. Scale bars: A, F. 1 mm, B–C, E, H–I. 2 mm, D and K. 5 mm, G. 3 mm, J. 4 mm

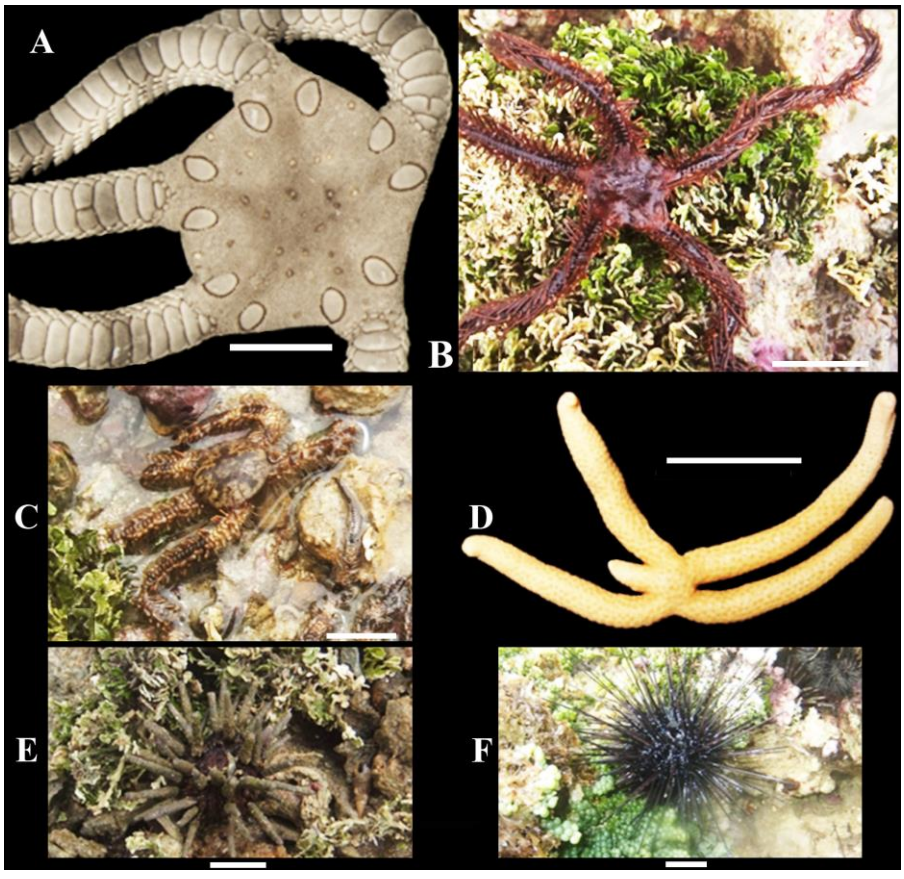

Figure 4. Echinoderms associated with reef ecosystems in Morro de São Paulo: A. *Ophioderma brevicauda*; B. *Ophiocoma echinate* dark brown; C. *Ophiocoma echinata* mottled brown; D. *Linckia guildingi*; E. *Eucidaris tribuloides*; F. *Diadema antillarum*. Scale bars: A. 1 cm, B–F. 3 cm

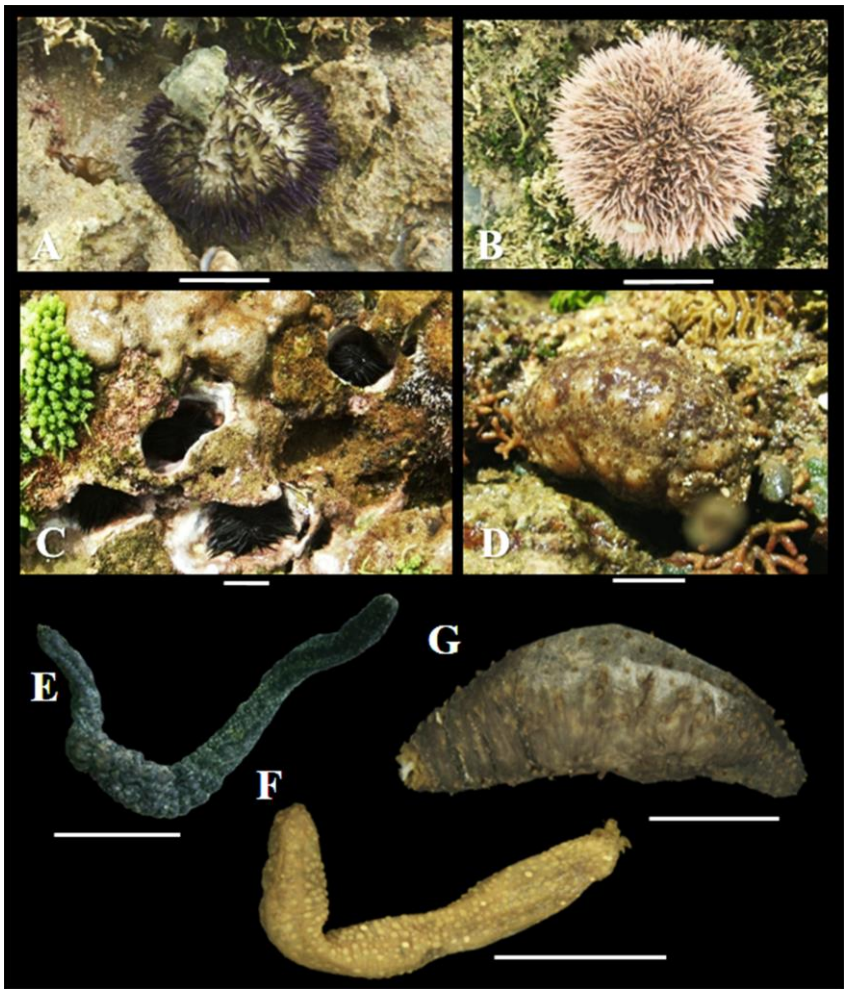

Figure 5. Echinoderms associated with reef ecosystems in Morro de São Paulo: A. *Lytechinus variegatus variegatus*; B. *Tripneustes ventricosus*; C. *Echinometra lucunter*; D. *Holothuria* (*Halodeima*) *grisea*; E. *Stolus cognatus*; F. *Chiridota rotifera*; G. *Holothuria* (*Thymiosycia*) *arenicola*. Scale bars: A. 4 cm, B–D. 3 cm, E. 2 cm, F–G. 1 cm

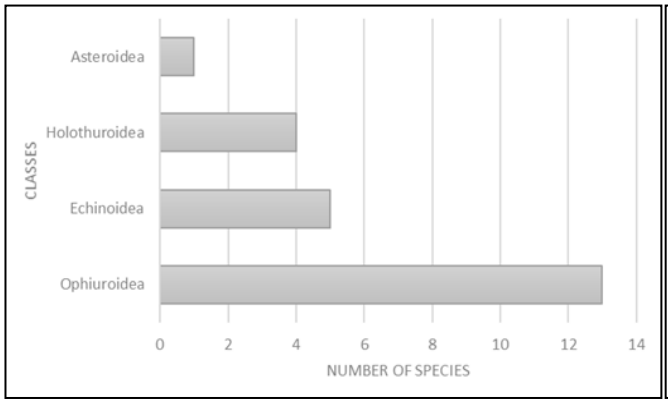

Figure 6. Species richness by classes of Echinodermata collected from Morro de São Paulo

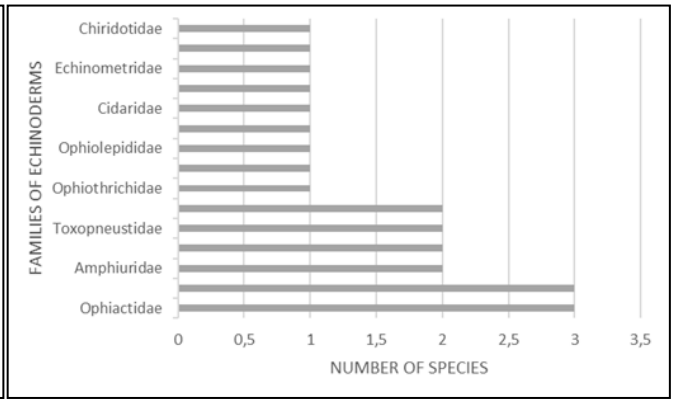

Figure 7. Species richness by families of Echinodermata collected from Morro de São Paulo

DISCUSSION

Despite the likely underestimations, a considerable diversity of pycnogonids and echinoderms was found in the present study. Pycnogonids are among the least sampled groups along the Brazilian coast (Tiago and Migotto, 1999), especially in the northeastern region of the country (Lucena *et al*., 2015). Despite recent efforts directed at the group, only eight species have been recorded for the coast of Bahia (Lucena *et al*., 2015; Lucena and Christoffersen, 2017; Lucena and Christoffersen, 2018a, b) and only a slightly higher number has been recorded for the entire northeastern region. As there is no inventory for the group in the region, present knowledge is based on sporadic records (Lucena and Chrisoffersen, 2018a). Pycnogonids are known for their low abundance (especially in warm waters), very small bodies and cryptic habits (Arango, 2003a; Arango and Krapp, 2007). Despite the modest sampling (three species), some frequently reported and very diverse groups in the Brazilian pycnogonid fauna, such as the genus *Anoplodactylus* Wilson, 1878 were not represented in the present survey. Future sampling efforts will certainly reveal greater diversity in the area. All species reported here were

collected on algae, as commonly observed for Brazilian shallow-water species (see Lucena and Christoffersen, 2018a). Algae constitute a good habitat for sea spiders in shallow waters (Arnaud and Bamber, 1987), serving as shelter and a source of food, with a diverse range of potential prey items (Arango, 2003b). Although widely distributed in the Western Atlantic (Child, 2004; Müller and Krapp, 2009), *Achelia sawayai* (Figure 2B−C), *Ammothella spinifera* Cole, 1904 (Figure 2A) and *Tanystylum isabellae* Marcus, 1940 (Figure 2D−E) are recorded here for the first time for the coast of Bahia, increasing the known species in the region to nine. The three pycnogonid species collected are commonly found in shallow waters: *Achelia sawayai* has been recorded at depths of 98 m (Müller, 1993); *Achelia sawayai* and *Ammothella spinifera* occur on a wide variety of substrates (e.g., mangrove roots, rocks) and encrusting organisms (e.g., ascidians, hydrozoans and sponges) as well as algae of the genera *Dictyota* J.V. Lamouroux, 1809, *Sargassum* C. Agardh, 1820, *Halimeda* J.V. Lamouroux, 1812, *Digenea* C. Agardh, 1822, and *Lithothamnion* Heydrich, 1897. *Tanystylum isabellae* has been recorded on hydrozoans of the genus *Thyroscyphus* Allman, 1877, and algae of the genus *Sargassum* (Müller, 1993; Müller and Krapp, 2009). As occurs with most other marine invertebrates, knowledge on Echinodermata in northeastern Brazil is fragmentary. Echinoderms on the coast of Bahia have been investigated by Alves and Cerqueira (2000), Manso (2004), Magalhães *et al*. (2005), Manso *et al*. (2008), Paim *et al*. (2015) and other authors in recent decades. Alves and Cerqueira (2000) and Manso *et al*. (2008) found between 28 and 33 species on different beaches along the coast of the city of Salvador (state of Bahia). In common with these studies, we found the species *Amphipholis squamata*, *Ophiothrix angulata*, *Ophiocoma echinata*, *Ophionereis squamulosa*, *Ophiactis lymani*, *O. savignyi* (Ophiuroidea) (see Alves and Cerqueira, 2000; Manso, 2004; Manso *et al*., 2008), *Linckia guildingi* (Asteroidea) (see Alves and Cerqueira, 2000; Manso *et al*., 2008), *Eucidaris tribuloides* and *Lytechinus variegatus variegatus* (Echinoidea) (see Manso *et al*., 2008). All echinoids identified by Alves and Cerqueira (2000) on five beaches in the city of Salvador are also reported for Morro de São Paulo in the present study. Paim *et al*. (2015) recorded 11 species of Ophiuroidea from Camamu Bay, nine of which were new records for the area. At the same locality, Manso (2004) inventoried 14 species of echinoderms, 10 of which were ophiuroids and one of these was a new species for science. Although these two studies were conducted at the same locality, there were only two species in common: *Microphiopholis atra* and *Ophiothrix* (*Ophiothrix*) *angulata*. This indicates the need for more faunal inventories to determine the real biodiversity of marine ecosystems on the northeastern coast of Brazil. The present study obtained about 32% of the echinoderm species known for the coast of Bahia (see Magalhães *et al*., 2005). Most species found are common in northeastern Brazil, with the exception of *Amphiura kinbergi* Ljungman, 1872, *Ophioderma brevicauda* Lütken, 1856 and *Tripneustes ventricosus* (Lamarck, 1816). This shows that the reef ecosystems of Morro de São Paulo exhibit an important biodiversity of invertebrates that have not been taxonomically studied over the years. The invertebrate community in the study area has certainly been affected by multiple anthropogenic impacts, such as pollution as well as the trampling and collecting of individuals by tourists and fishermen. Populations of sea stars and macromollusks (see Lima *et al*. (2019) for information on mollusks) have most likely suffered severe impacts and declines at the study site due to the selling of endoskeletons and shells in the local marketplace. Further studies in the region are needed to increase knowledge on the invertebrate fauna and gain a better understanding of the impact of human activities (pollution and tourism) on these communities (Almeida *et al*., 2007). Moreover, local governments need to develop conservation strategies and act more effectively to prevent the capture of threatened invertebrates.

Acknowledgments

We appreciate the facilities provided by the Federal University of Paraíba, Brazil (Paulo Young Invertebrate Laboratory [LIPY]). R.A. Lucena acknowledges the doctoral scholarship received from *Coordenação de Aperfeiçoamento do Ensino Superior* (CAPES [Coordination for the Advancement of Higher Education Personnel]). Research by J. Prata and M. L. Christoffersen is supported by *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq [National Council of Scientific and Technological Development]) (process number: 158676/2018-1 and 301288/2018-6, respectively).

REFERENCES

Absalão RS. 2005a. Soft-bottom molluscs of the Abrolhos Bank. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 82–86.

Absalão RS. 2005b. Molluscs recorded during the Abrolhos RAP survey. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 126–133.

Albuquerque MN, Guille A. 1991. Ophiuroidea (Echinodermata) ao largo do Brasil: Banco dos Abrolhos, Cadeia Submarina Vitória-Trindade e Plataforma Continental Adjacente. Bol. Mus. Nac. 353:1–30.

Almeida AO, Coelho PA, Santos JTA, Ferraz NR. 2007. Crustáceos estomatópodos e decápodos da costa de Ilhéus, Bahia, Brasil. Atlântica. 29:5–20.

Alves OFS, Cerqueira WRP. 2000. Echinodermata das praias de Salvador (Bahia, Brasil). Rev. Bras. Zool. 17:543–553.

Amaral ACZ, Jablonski S 2005. Conservação da biodiversidade marinha e costeira no Brasil. Megadiversidade. 1:43–51.

Arango CP 2003a. Molecular approach to the phylogenetics of sea spiders (Arthropoda: Pycnogonida) using partial sequences of nuclear ribosomal DNA. Mol. Phylogenet. Evol. 28:588–600.

Arango CP, Krapp F. 2007. A new species of *Anoplodactylus* (Arthropoda: Pycnogonida) from the Great Barrier Reef and discussion on the *A. tenuicorpus*-complex. Zootaxa. 1435:19–24.

Arango CP. 2003b. Sea spiders (Pycnogonida, Arthropoda) from the Great Barrier Reef, Australia: new species, new records and ecological annotations. J. Nat. Hist. 37:2723–2772.

Arnaud F, Bamber RN. 1987. The biology of Pycnogonida. Adv. Mar. Biol. 24:1–96.

Benavides-Serrato M, Borrero-Pérez GH, Diaz-Sanchez CM 2011. Equinodermos del Caribe colombiano I: Crinoidea,

Asteroidea y Ophiuoridea. Santa Marta: Serie de PublicacionesEspeciales de Invemar. 388 p.

Borges M, Amaral ACZ. 2005. Filo Echinodermata. In: Amaral ACZ, Rizzo AE, Arruda EP (eds) Manual de Identificação dos Invertebrados Marinhos da Região Sudeste-Sul do Brasil. São Paulo: Editora da Universidade de São Paulo, pp 235–283.

Borges M, Monteiro AMG, Amaral AC. 2002. Taxonomy of Ophiuroidea (Echinodermata) from the continental shelf and slope of the Southern and Southeastern Brazilian coast. Biota Neotrop. 2:1–69.

Borrero-Pérez GH, Benavides-Serrato M, Diaz-Sanchez CM 2012. Equinodermos del Caribe colombiano II: Echinoidea y Holothuroidea. Santa Marta: Serie de PublicacionesEspeciales de Invemar. 252 p.

Castro CB, Segal B, Pires DO, Medeiros MS. 2005a. Distribution and diversity of coral communities in the Abrolhos reef complex, Brazil. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 1–39.

Castro CB, Segal B, Pires DO, Medeiros MS. 2005b. Reef anthozoan and hydrocoral taxa recorded for the Abrolhos Area. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 96–97.

CEPLAC. 1975. Comissão Executiva do Plano de Recuperação da Lavoura Cacaueira. Recursos Florestais. Diagnóstico Sócio-econômico da Região Cacaueira n 7. Ilhéus. Fortaleza: CEPLAC/IICA. 280 p.

Child CA. 2004. Some Pycnogonida from the western Caribbean with descriptions of three new species. Bull. Mar. Sci. 74:143–161.

Costa Jr. OS, Leão ZMAN, Nimmo M, Attrill MJ. 2000. Nutrification impacts on coral reefs from northern Bahia, Brazil. Hydrobiologia. 440:307–315.

Cruz I, Kikuchi RKP, Leão ZMAN. 2009. Caracterização dos recifes de corais da Unidade de Conservação Baía de Todos os Santos para fins de manejo, Bahia, Brasil. Rev. Gest. Cost. Integr. 9:3–23.

Dutra GF, Allen GR, Werner T, Mckenna SA. 2005. A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Washington: RAP Bulletin of Biological Assessment, Conservation International. 160 p.

Elliff CI, Kikuchi RKP. 2017. Ecosystem services provided by coral reefs in a Southwestern Atlantic Archipelago. Ocean Coast Manag. 136:49–55.

Freitas LM, Oliveira MDM, Leão ZMAN, Kikuchi RKP. 2019. Effects of turbidity and depths on the bioconstruction of the Abrolhos reefs. Coral Reefs. 38:241–253.

Hendler G, Miller JE, Pawson DL, Kier PM. 1995. Sea stars, sea urchins and allies: Echinoderms of Florida and the Caribbean. Washington: Smithsonian Institution Press. 392 p.

Hetzel B, Castro CB. 1994. Corais do Sul da Bahia. Rio de Janeiro: Nova Fronteira. 189 p.

INEMA. 2016. APA das ilhas de Tinharé e Boipeba. Salvador: Instituto do Meio Ambiente e Recursos Hídricos.

Kikuchi RKP, Oliveira MDM, Leão ZMAN, Silva RM, Martins PMR. 2008. Os Recifes de Tinharé-Boipeba-Camamu, Bahia. Rio Oil Gas Expo Confer. 2008:1–8.

Krug LA, Gherardi DFM, Stech JL, Leão ZMAN, Kikuchi RKP. 2012. Characterization of coral bleaching environments and their variation along the Bahia State coast, Brazil. Int. J. Remote Sens. 33:4059–4074.

Leão ZMAN, Kikuchi KP, Oliveira MDM. 2008a. Branqueamento de corais nos recifes da Bahia e sua relação com eventos de anomalias térmicas nas águas superficiais do oceano. Biota Neotrop. 8:69–82.

Leão ZMAN, Kikuchi RKP, Ferreira BP, Neves EG, Sovierzoski HH, Oliveira MDM, Maida M, Correia MD, Johnsson R. 2016. Brazilian coral reefs in a period of global change: A synthesis. Braz. J. Oceanogr. 64:97–116.

Leão ZMAN, Kikuchi RKP, Testa V. 2003. Corals and Coral Reefs of Brazil. In: Cortés J (ed) Latin America Coral Reefs. Amsterdam: Elsevier Science, pp 9–52.

Leão ZMAN, Oliveira MDM, Kikuchi RKP (2008b). Os recifes de coral da APA Ponta da Baleia, Bahia. OLAM Ciência Tecnologia. 8:287–315.

Lima SFB, Lima BV, Abreu EC, Oliveira GSP, Lucena RA, Mendonça LMC, Prata J, Souza JWS. 2019. First inventory of benthic mollusks associated with the reef ecosystems of Morro de São Paulo on Tinharé Island in northeastern Brazil. Biota Neotrop. 19:e20190745.

Loiola M, Cruz ICS, Leão ZMAN, Kikuchi RKP. 2014. Definition of priority areas for the conservation of a coastal reef complex in the eastern Brazilian coast. Rev. Gest. Cost. Integr. 14:611–624.

Lucena RA, Araújo JP, Christoffersen ML. 2015. A new species of *Anoplodactylus* (Pycnogonida: Phoxichilidiidae) from Brazil, with a case of gynandromorphism in *Anoplodactylus eroticus* Stock, 1968. Zootaxa. 4000:428–444.

Lucena RA, Christoffersen ML. 2017. Pycnogonida (Arthropoda) from the Abrolhos Archipelago, Brazil, including a new species of *Callipallene* Flynn, 1929. Mar. Biodivers. 47:461–468.

Lucena RA, Christoffersen ML. 2018a. An annotated checklist of Brazilian sea spiders (Arthropoda: Pycnogonida). Zootaxa. 4370:101–122.

Lucena RA, Christoffersen ML. 2018b. *Anoplodactylus* (Pycnogonida: Phoxichilidiidae) from Brazil, new records and two new species. Turk. J. Zool. 42:372–388.

Magalhães WF, Martins LR, Alves OFS. 2005. Inventário dos Echinodermata do estado da Bahia. Braz. J. Aquat. Sci. Tech. 9:61–65.

Manso CLC, Alves OFS, Martins L. 2008. Echinodermata da Baía de Todosos Santos e Baía de Aratu (Bahia, Brasil). Biota Neotrop. 8:179–196.

Manso CLC. 2004. Os Echinodermata da bacia de Camamu, Bahia, Brasil. Biol. GeralExper. 5:19–25.

Marcus E. 1940. Os pantopoda brasileiros e os demais sul-americanos. Bol. Fac. Filos. Cienc. Let. Univ. São Paulo. 19:3–179.

Martins L, Souto C, Braga J, Tavares M. 2018. Echinoidea and Holothuroidea (Echinodermata) of the Trindade and Martin Vaz Archipelago, off Brazil, with new records and remarks on taxonomy and species composition. J. Mar. Biol. Assoc. U. K. 98:521–555.

Mazzei EF, Bertoncini AA, Pinheiro HT, Machado LF, Vilar CC, Guabiroba HC, Costa TJF, Bueno LS, Santos LN, Francini-Filho RB, Hostim-Silva M, Joyeux J.-C (2016). Newly discovered reefs in the southern Abrolhos Bank,

Brazil: Anthropogenic impacts and urgent conservation needs. Mar. Pollut. Bull. 114:123–133.

Miranda RJ, Cruz ICS, Leão ZMAN. 2013. Coral bleaching in the Caramuanas reef (Todosos Santos Bay, Brazil) during the 2010 El Niño Event. *Lat. Am. J. Aquat. Res.* 41:351–360.

MMA. 2002. Biodiversidade Brasileira. Brasília: MMA/SBF. 404 p.

MMA. 2010. Panorama da conservação dos ecossistemas costeiros e marinhos no Brasil. Brasília: MMA/SBF/GBA. 150 p.

Moura RL, Amado-Filho GM, Moraes FC, Brasileiro PS, Salomon PS, Mahiques MM, Bastos AC, Almeida MG, Silva Jr. JM, Araujo BF, Brito FP, Rangel TP, Oliveira BCV, Bahia RG, Paranhos RP, Dias RJS, Siegle E, Figueiredo Jr. AG, Pereira RC, Leal CV, Hajdu E, Asp NE, Gregoracci GB, Neumann-Leitão S, Yager PL, Francini-Filho RB, Fróes A, Campeão M, Silva BS, Moreira APB, Oliveira L, Soares AC, Araujo L, Oliveira NL, Teixeira JB, Valle RAB, Thompson CC, Rezende CE, Thompson FL. 2016. An extensive reef system at the Amazon River mouth. Sci. Adv. 2016:e1501252.

Müller HG, Krapp F. 2009. The pycnogonid fauna (Pycnogonida, Arthropoda) of the Tayrona National Park and adjoining areas on the Caribbean coast of Colombia. Zootaxa. 2319:1–138.

Müller HG. 1993. World catalogue and bibliography of the recent Pycnogonida. Wetzlar: Wissenschaftlicher Verlag. 388 p.

Paim FB, Guerrazzi MC, Borges M. 2015. Descriptive and illustrated diagnosis of Ophiuroidea fauna (Echinodermata) in the shallow waters of Northeastern Brazil. Mar. Biodivers. Rec. 8:1–17.

Paiva PC. 2005a. Soft-bottom polychaetes of the Abrolhos Bank. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 87–90.

Paiva PC. 2005b. List of polychaetes recorded during the Abrolhos RAP survey. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 134–136.

Rhormens MS, Pedrini AG, Ghilardi-Lopes NP. 2017. Implementation feasibility of a marine ecotourism product on the reef environments of the marine protected areas of Tinharé and Boipeba Islands (Cairu, Bahia, Brazil). Ocean Coast Manag. 139:1–11.

Silva AS, Leão ZMAN, Kikuchi RKP, Costa A, Souza JRB. 2013. Sedimentation in the coastal reefs of Abrolhos over the last decades. Cont. Shelf Res. 70:159–167.

Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña ZA, Finlayson M, Halpern BS, Jorge MA, Lombana A, Lourie AS, Martin KD, Mcmanus E, Molnar J, Recchia CA, Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience. 57:573–583.

Tiago CG, Migotto AE1999. Filo Cheliceriformes. In: Migotto AE, Tiago CG (eds) Biodiversidade do Estado de São Paulo, Brasil: síntese do conhecimentoao final do século XX, 3: Invertebrados marinhos. São Paulo: FAPESP. pp199–206.

Tommasi LR. 1969a. Lista dos Holothuroidea recentes do Brasil. Contr. Avuls. Inst. Oceanogr.Univers. São Paulo. 15:1–50.

Tommasi LR. 1969b. Nova contribuição à lista dos Crinóides recentes do Brasil. Contr. Avuls. Inst. Oceanogr. Univers. São Paulo. 17:1–8.

Tommasi LR. 1970a. Lista dos Asteróidesrecentes do Brasil. Contr. *Avuls. Inst. Oceanogr. Univers. São Paulo*. 18:1–161.

Tommasi LR. 1970b. Os Ofiuróides recentes do Brasil e de regiões vizinhas. Contr. Avuls. Inst. Oceanogr. Univers. São Paulo. 20:1–146.

Vasconcellos MJO, Leão ZMAN, Kikuchi RKP. 2018. Coral reef gowth pattern in eastern Brazil has not changed since the Holocene. Quat. Environ. Geosci. 9:49–61.

Young PS, Serejo CS. 2005a. Crustacea of the Abrolhos Region, Brazil. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 91-95.

Young PS, Serejo CS 2005b. List of crustacean species recorded from the Abrolhos region (including the nearby coast) indicating habitat, range within Brazil, and general distribution. In: Dutra GF, Allen GR, Werner T, McKenna SA (eds) A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Volume 38. Washington: RAP Bulletin of Biological Assessment, Conservation International, pp 137-156.

****