



New record of the Six-holed Keyhole Urchin, *Leodia sexiesperforata* (Leske, 1778) (Clypeasteroidea, Mellitidae), from the Brazilian coast, with an updated distribution map

Carlos Eduardo Rocha Duarte Alencar,^{1,2} Valéria Fonsêca Vale,² Sávio Arcanjo Santos Nascimento Moraes,² Paulo Victor Nascimento Araújo,^{2,3} Fúlvio Aurélio Morais Freire²

1 Instituto Nacional de Ciência e Tecnologia/Universidade Federal da Bahia, Instituto de Geociências, Rua Barão de Jeremoabo, Ondina, 40170-115 Salvador, Brazil. **2** Grupo de Estudos em Ecologia e Fisiologia de Animais Aquáticos/Universidade Federal do Rio Grande do Norte, Departamento de Biologia, Ecologia e Zoologia, Centro de Biociências, Campus Universitário Lagoa Nova, Caixa Postal 1524, CEP 59078-970, Natal, RN, Brazil. **3** Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Norte, Campus Macau, CEP 59500-000, Macau, RN, Brazil.

Corresponding author: Carlos Eduardo Rocha Duarte Alencar, carlosee2002@gmail.com

Abstract

A new record of *Leodia sexiesperforata* is reported from the coast of Rio Grande do Norte state, northeastern Brazil. An updated distribution map based on data collected from literature, museums, and scientific collections is also presented. This new report fills a distribution gap on the coast of northeastern Brazil. *Leodia sexiesperforata* has a continuous range between the states of Ceará and Alagoas.

Key words

Sand dollars; Echinoidea; distribution gap; Atlantic Tropical ecoregion.

Academic editor: Sérgio Stampar | Received 28 August 2016 | Accepted 11 July 2017 | Published 6 October 2017

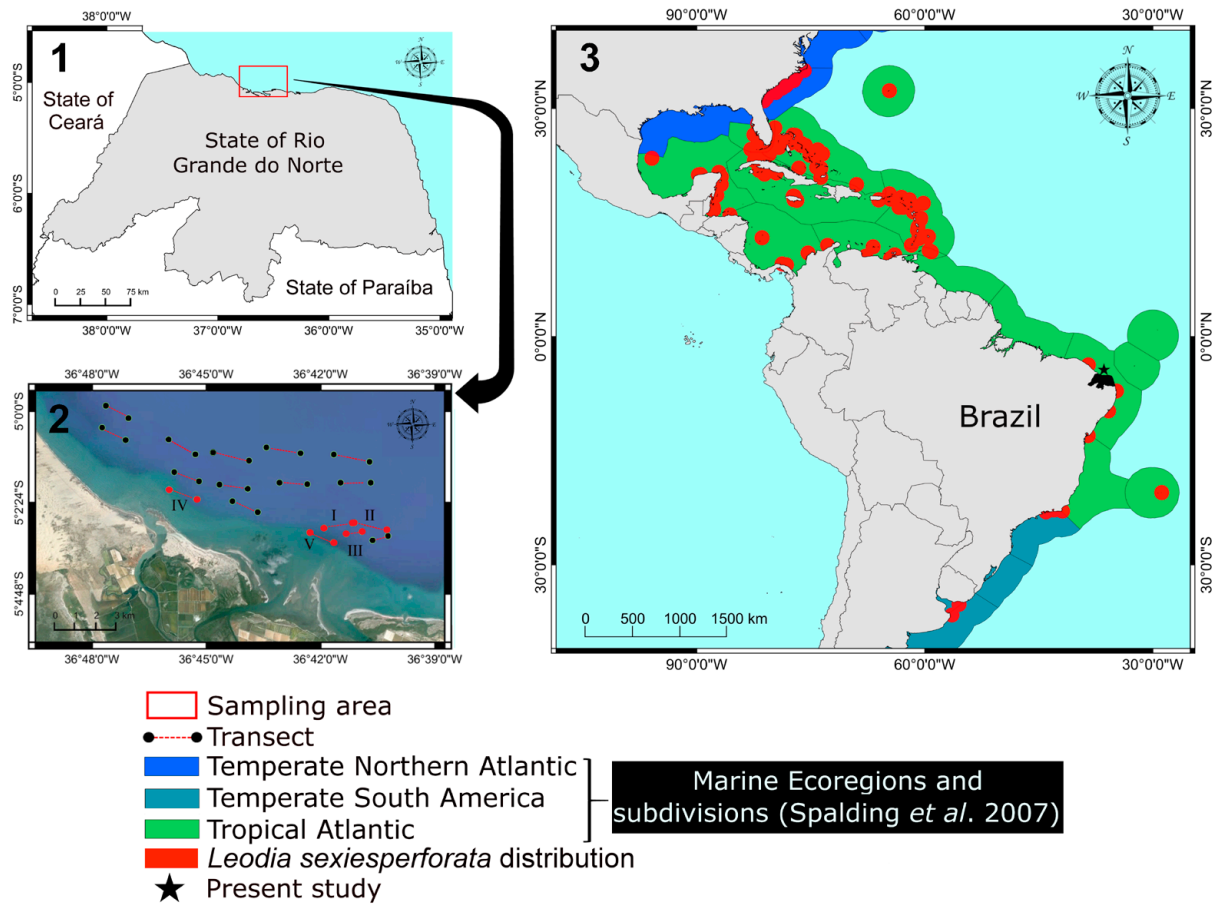
Citation: Alencar CERD, Vale VF, Moraes SASN, Araújo PVN, Freire FAM (2017) New record of the Six-holed Keyhole Urchin, *Leodia sexiesperforata* (Leske, 1778) (Clypeasteroidea, Mellitidae), from the Brazilian coast, with an updated distribution map. Check List 13 (5): 597–603. <https://doi.org/10.15560/13.5.597>

Introduction

The Six-holed Keyhole Urchin, *Leodia sexiesperforata* (Leske, 1778) (Clypeasteroidea, Mellitidae), is an irregular Echinoidea with a wide distribution along the coast of the Americas, from eastern North America to Uruguay (Clark 1933, Mooi and Peterson 2000), with records from the United States of America, Mexico, Belize, Bahamas, Cuba, Puerto Rico, Barbados, Venezuela, and Brazil. Clark (1933) stated that this species occurs in Jamaica, Saint Kitts, Martinique, Saint Vincent, and Tobago. Herrera-Moreno and Bitencourt (2013) listed *L. sexiesperforata* as occurring in Honduras, Costa Rica,

Dominican Republic, Panama, Colombia, and Uruguay. In Brazil, its distribution is widely known, but with some gaps, and has been recorded from the states of Ceará, Paraíba, Pernambuco, Alagoas, Bahia, Espírito Santo, and Rio de Janeiro (Rathbun 1879, Lima-Verde 1969, Alves and Cerqueira 2000, Ventura et al. 2006, Gondim et al. 2008, Miranda et al. 2012).

The Brazilian Northeastern Region extends for over 19 degrees in latitude (between 01°02'30" N and 18°20'07" S), comprising a coastline of approximately 3400 km, and holding a wide variety of coastal environments such as beaches, dunes, cliffs, estuaries, deltas, sandbanks, islands, and coral reefs, among oth-



Figures 1–3. Sampling site in Rio Grande do Norte (1 and 2) and updated distribution map (3) for *Leodia sexiesperforata* (Leske, 1778). Highlighted transects sampled in the species collection campaign (Roman algorithm) and marine realms, and their subdivisions proposed by Spalding et al. (2007).

ers (Pinheiro et al. 2008). In this region, pioneering work includes the publications of Verrill (1868), studying material collected in Abrolhos Archipelago, Bahia coast; Rathbun (1879), with collections conducted in several sites of the Brazilian coast including the northeastern region; and Lima-Verde (1969), with collections from Piauí (Parnaíba river mouth) to Alagoas (São Francisco river mouth).

Recently faunistic inventories of Echinodermata in northeastern Brazil have been published for the following states: Maranhão (Gondim et al. 2013), Piauí (Gondim and Giacometti 2010, Gondim et al. 2013), Ceará (Martins and Queiroz 2006, Manso et al. 2014), Paraíba (Gondim et al. 2008, Gondim et al. 2014a), Pernambuco (Fernandes et al. 2002, Lima and Fernandes 2009), Alagoas (Lima et al. 2011, Miranda et al. 2012), and Bahia (Alves and Cerqueira 2000, Magalhães et al. 2005, Manso et al. 2008). The few data from Sergipe state comes from an inventory by Oliveira et al. 2010, who also includes materials from other states in the Northeast Region such as Paraíba, Alagoas, and Bahia. For Rio Grande do Norte, until now, publications are Lima-Verde (1969) with samples in Rocas Atoll and in Maracajaú beach, and Gondim et al. (2012, 2014b, 2015a, 2015b, 2015c) and Manso et al. (2014) with samplings conducted from the continental shelf.

Despite the above-mentioned papers, the knowledge of echinoderm biodiversity in Brazil remains sparse (Ventura et al. 2006), especially in the Northeastern Region (Miranda et al. 2012). Thus, the aim of this paper is to report the first record of *L. sexiesperforata* from the coast of Rio Grande do Norte and provide an updated distribution map based on literature and field samples.

Methods

Between June 2013 and February 2015 seasonal benthic biodiversity expeditions were conducted on the shallow continental shelf off the Porto do Mangue region of Rio Grande do Norte, northeastern Brazil (Fig. 1). The timing of the surveys was determined based on the historic rainfall data for Porto do Mangue municipality over a period of 10 years (1992–2012) provided by EMPARN (Empresa de Pesquisa Agropecuária do Rio Grande do Norte). Thus, the expeditions were scheduled for the dry (March–May and June–August) and rainy season (September–November and December–February). In each expedition, trawl fishing for biological collections was conducted at georeferenced sites (Fig. 2) by utilizing an artisanal trawl fishing boat. In addition, environmental data were collected, including depth (in meters), water transparency, temperature, salinity, dissolved oxygen, and pH from the water

column bottom. The capture effort in each site had 20 min duration at an approximate speed of 2 knots, with a 4 mm mesh fishing net reaching the bottom.

The sand dollars were identified following what was introduced by Tommasi (1966) and Hendler et al. (1995). Later, the specimens were stored in 70% alcohol and deposited at the collection of Grupo de Estudos em Ecologia e Fisiologia de Animais Aquáticos (GEEFAA), with the voucher number GEEFAA/UFRN-361.

Collection data from this study (primary data) were compiled along with a bibliographic survey (secondary data) to prepare an updated distribution map of *L. sexiesperforata*. Geographic coordinate data were gathered information from 2 different sources. The first source was the reviewing of publications, lists of specimens, biodiversity surveys, and scientific reports (Table 1). The second source was the revision of deposited material in scientific collections of research institutes and museums accessible through the Global Biodiversity Information Facility (GBIF 2013). Records without precise taxonomy, invalid geographic coordinates, or missing information on the collection and the institutions to which they belonged were disregarded. Fossils were ignored as well, because

they escaped the goal of this survey. Lastly, occurrences having no geographic coordinates but with satisfactory sampling location details had their location estimated using Google Earth Pro® software version 7.1.2.2041.

Facilities consulted using the GBIF directory were: California Academy of Sciences (CAS), Centro de Investigación y de Estudios Avanzados Unidad Mérida, Instituto Politécnico Nacional (CINVESTAV-IPN), Florida Museum of Natural History (FLMNH), Colección Nacional de Equinodermos Mexicanos (ICML-DF, UNAM), Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” (MACN), Marine Resources Research Institute (MRRI-SCDNR), Museum of Comparative Zoology, Harvard University (MCZ), Natural History Museum Rotterdam (NL), National Ocean and Atmospheric Administration–National Benthic Inventory (NBI-NOOA 2001 Grays Reef National Marine Sanctuary), REVIZEE Project Central Score (Lavrado and Ignacio 2006), and National Museum of Natural History, Smithsonian Institution (NMNH DwC-Archive, information provided with the permission of the NMNH).

All obtained data (primary and secondary) were compiled and added to a geospatial database, and the

Table 1. *Leodia sexiesperforata* occurrences from literature data. Present study highlighted in bold.

Author(s)	Locality (State)	Country	Latitude	Longitude
Mooi (1986a)	New Brunswick (North Carolina)	USA	33°42'56.14" N	078°13'24.48" W
	Florida Keys (Florida)		24°29'16.82" N	081°45'56.89" W
Mooi (1986b)	Pigeon Key (Florida)	USA	24°42'5.99" N	081°9'16.86" W
Telford & Mooi (1986)	Long Key (Florida)	USA	24°48'30.68" N	080°48'59.24" W
Solis-Marin et al. (2011)	NA*	Mexico	NA*	NA*
Kier (1975) ¹	Carrie Bow Cay	Belize	16°48' N	088°05' W
McClintock & Marion (1993) ¹	San Salvador	Bahamas	24°04' N	074°35' W
Campos & Solis-Marin (1998) ¹	Baía de Cardenas	Cuba	23°00' N	081°16' W
Clark (1933)	Arroyo	Puerto Rico	17°57'22.91" N	066°04'13.53" W
Telford (1978, 1982)	Rockley Beach (Bridgetown)	Barbados	13°4'20.44" N	059°35'21.15" W
Zoppi de Roa (1967) ²	Golfo Cariaco	Venezuela	10°30'24.63" N	064°4'10.95" W
	Cumaná		10°27'22.97" N	064°14'58.40" W
	Isla de Coche		10°45'04.03" N	063°58'7.83" W
	Bahía de Mochima (Sucre)		10°17'47.75" N	064°30'13.89" W
	Cata (Aragua), Playa Grande (Vargas), Quizandal (Carabobo), Punta Morón (Carabobo)		10°34'14.30" N	067°47'32.47" W
	Archipiélago de los Roques		11°48'32.88" N	066°48'34.57" W
Edwards (1973) ²	Cumaná	Venezuela	10°27'22.97" N	064°14'58.40" W
Lima-Verde (1969) ¹	Meireles Beach (Ceará)	Brazil	03°43'09.34" S	038°29'29.48" W
Present study	Porto do Mangue (Rio Grande do Norte)	Brazil	05°02'18.6" S	036°45'14.3" W
Gondim et al. (2008) ¹	Cabo Branco Beach (Paraíba)	Brazil	07°08'50" S	034°47'51" W
Rathbun (1879)	(Pernambuco)	Brazil	NA**	NA**
Miranda et al. (2012) ¹	Francês Reef (Alagoas)	Brazil	09°46'03" S	035°50'13" W
Queiroz et al. (2011) ¹	Praia de Porto da Barra (Bahia)	Brazil	13°00'24" S	038°31'48" W
Alves & Cerqueira (2000)	Salvador (Bahia)	Brazil	13°01'26.36" S	038°30'30.47" W
Magalhães et al. (2005)	Baía de Todos os Santos, Praia de Itapuan, Praia da Ribeira (Bahia)	Brazil	13°01'26.36" S	038°30'30.47" W
Manso et al. (2008) ¹	Baía de Todos os Santos (Bahia)	Brazil	12°51'18.85" S	038°36'25.87" W
Ventura et al. (2006) ¹	Ilha Martin Vaz (Espírito Santo)	Brazil	20°30'46.8" S	028°50'31.2" W
Rathbun (1879)	Baía do Rio de Janeiro (Rio de Janeiro)	Brazil	22°46'35.46" S	043°07'48.78" W

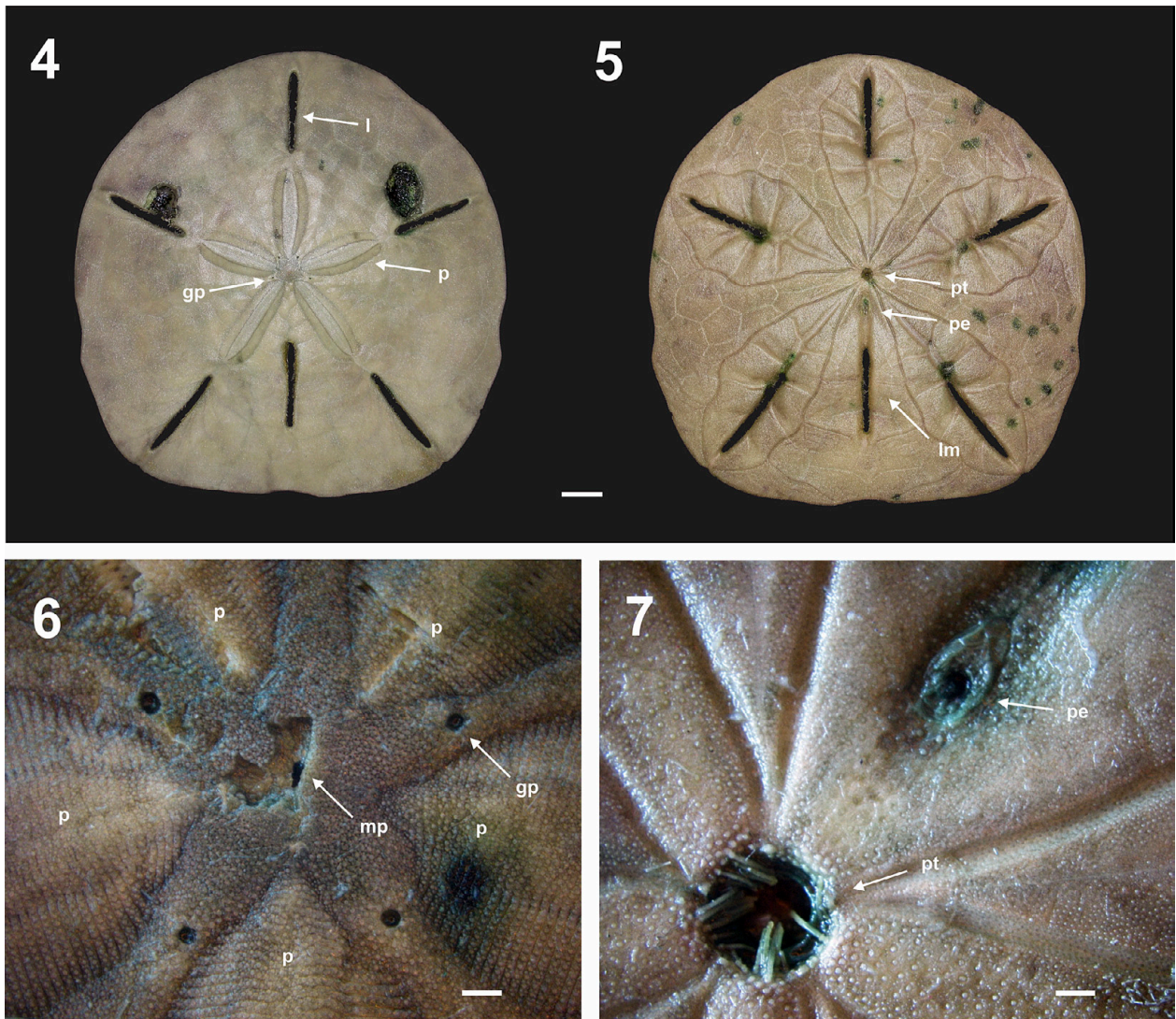
¹ Original geographic coordinates (other coordinates were estimated, see Methods for further information).

² Apud Francisco and Pauls (2008).

* Locality and geographic coordinates not available.

** Geographic coordinate not available.

NA: Not available.



Figures 4–7. *Leodia sexiesperforata* (Leske, 1778). **4.** Aboral view. **5.** Oral view. **6.** Detail of the apical system. **7.** Detail of the central region in the oral view. l = lunule, p = petals, gp = genital pore, pt = peristoma, pe = periproct, lm = median posterior lunula, mp = madreporite plate. Scale bars 4 and 5: 10 mm. Scale bars 6 and 7: 1 mm.

resulting tables were imported into QuantumMap 2.14.0 (QGIS Development Team 2016) software using the datum WGS84. Marine ecoregion delimitations, as proposed by Spalding et al. (2007), were added. These were obtained through the Marineregions.org (<http://www.marineregions.org>) online portal. Lastly, each occurrence of the species underwent a 1° buffer, and the final updated geographic distribution map of *L. sexiesperforata* was generated.

Results

Class Echinoidea Leske, 1778
 Order Clypeasteroidea Agassiz, 1872
 Suborder Scutellina Haeckel, 1896
 Family Mellitidae Stefanini, 1912
 Genus *Leodia* Gray, 1851

Leodia sexiesperforata (Leske, 1778)

Material examined. Brazil: Rio Grande do Norte: shallow continental shelf of Rio Grande do Norte, Porto do

Mangue municipality, 2 specimens, 05°02'18.6" S, 036°45'14.3" W, 3-II-2015, (voucher GEEFAA/UFRN 361) (Figs 4–7).

Additional material. Brazil: Paraíba: Beach rocks ferruginous sandstone, Cabo Branco Beach, João Pessoa municipality, 07°08'50" S, 034°47'51" W, voucher UFPB.ECH 1163 (Gondim et al. 2008).

Diagnosis. Test subcircular, flat, dorsally elevated in middle portion, with thin delicate edge and flat oral surface (Figs 4, 5). Five short petals, similar in length (Fig. 4). Apical disk with 4 genital pores (Fig. 6). Six similar lunules, narrow and elongate, including 5 ambulacral lunules and 1 anal lunule (Figs 4, 5). Peristome situated in middle of oral surface (Fig. 5). Periproct placed in the oral region between peristome and the anal lunule and positioned closer to peristome (Fig. 7).

One specimen of *L. sexiesperforata* was captured at site IV and another at site V, both during the 2015 December–February expedition (sample in February) (Fig. 1). These

specimens represent the first record of this species from the Rio Grande do Norte coast (Table 1). Both sample sites IV and V presented similar abiotic factors such as depth, salinity, dissolved oxygen, and pH. Water transparency and bottom temperature were equal at both sites (Secchi = 1.5 m, Temperature = 28.5 °C). Average depth at both sample sites was 3.5 m (Table 2). In addition, the region where both sites are located is mostly formed by predominantly sand sediments.

Discussion

The geographic distribution of *L. sexiesperforata* is situated entirely within 3 marine realms: Temperate Northern Atlantic, Tropical Atlantic, and Temperate South America (Fig. 3). The Temperate Northern Atlantic shows a predominance of records from the east coast of the United States, Carolinian Ecoregion. In the Tropical Atlantic, the data comes from 2 broad areas divided by an extensive gap. The first is in the Caribbean and along the southeastern coast of the United States (Tropical Northwestern Atlantic province), with the most number of occurrences of *L. sexiesperforata*. The second area extends from the Brazilian Northeast Region as far south as the Cabo Frio resurgence zone at the southern limit of the Tropical Southwestern Atlantic province, Rio de Janeiro; here information is sparse and there are multiple gaps in the known distribution of *L. sexiesperforata*. Between these 2 areas the North Brazilian Shelf province (from the state of Piauí to Venezuela) has no record of this species. Lastly, records of *L. sexiesperforata* are known from the Warm Temperate Southwestern Atlantic province, with a distribution gap between the Brazilian Southeast Region and Uruguay (Fig. 3).

The new record of *L. sexiesperforata* from Rio Grande do Norte fills the gap in the known distribution of the species. Therefore, the distribution of this species extends continuously along the Brazilian Northeast coast from Ceará to Alagoas. Recent studies, such as by Gondim et al. (2013) with material collected along the coast of Maranhão and Piauí and Oliveira et al. (2010), who includes few materials collected on the coast of Sergipe, have not reported the occurrence of *L. sexiesperforata*, but this might be due to a lack of sampling.

The distribution gaps of macrobenthic species on the northeast Brazilian coast may be due to the sparsity of surveys, although there has been an increase in recent records. This is particularly highlighted along the coast of Rio Grande do Norte state, where recent surveys

for benthic biodiversity and accidental sampling has accounted for new records (Gondim et al. 2012, 2015a, 2015b, 2015c, Manso et al. 2014, Moraes et al. 2015) and ecological interactions (Alencar et al. 2014). Thus, continuous benthic biodiversity surveys along the Brazilian northeast coast is paramount for a better understanding of the geographic distribution of *L. sexiesperforata*.

It is known that Echinodermata have a fundamental role in marine environments (Benitez-Villalobos 2001), occupying several trophic levels in the food chain (herbivore, carnivore, detritophage, and omnivore), regulating the density of species, participating in the recycling of nutrients, bioerosive processes, and even in the epibiosis with other animals and plants (Caso 1978, Hadel et al. 1999, Ventura et al. 2006). Therefore, new records, such as those presented hereby, not only contribute to a better knowledge of the fauna but also aid in evolutionary and marine conservation studies.

Acknowledgements

We are thankful for the scholarships offered (Carlos ERD Alencar, CAPES/Brazil; Valéria F Vale and Sávio ASN Moraes, CNPq/Brazil), for funding the research project (CNPq/MPA #407046/2012-7) and GBIF management. We also thank Dr Anne I. Gondim for confirming the identity of the species and the anonymous reviewers for their criticism and assistance on improving this manuscript. The lab Grupo de Estudos em Ecologia e Fisiologia de Animais Aquáticos/GEEFAA for field and laboratory assistance, and the fishermen and fishing community of Porto do Mangue for field assistance. All collections were made according to state and federal laws (SISBIO/ICMBIO 28314-1).

Authors' Contributions

CERDA wrote the text, identified the specimens, and prepared the figures and tables; VFV collected the data, revised literature, and wrote the text; SASNM collected the data, wrote the text, and made the figures and tables; PVNA wrote the text, and made the figures and tables; FAMF identified specimens, reviewed literature, wrote the text, and revised the text.

References

- Alencar CERD, Moraes AB, Moraes SASN, Araújo PVN, Freire FAM (2014) First record of the association between the porcellanid crab *Porcellana sayana* Leach, 1820 and the brachyuran crab *Stratiolib-*

Table 2. Abiotic factors in each sample point where *Leodia sexiesperforata* was captured. CLT = current local time, Dep = depth, Secchi = water transparency, T = bottom temperature of the water column, Sal = bottom salinity of the water column, DO = dissolved oxygen.

	Latitude	Longitude	CLT (GMT -03:00)	Dep (m)	Secchi (m)	T (°C)	Sal	DO (mg/L)	pH
Transect IV	05°02'18.6" S	036°45'14.3" W	12:10	3.8	1.5	28.5	37.38	5.23	8.77
	05°02'3.7" S	036°45'58.5" W							
Transect V	05°03'26.8" S	036°41'39.8" W	11:05	3.2	1.5	28.5	36.69	5.97	8.91
	05°03'11.2" S	036°42'17.5" W							

- inia bellicosa* Oliveira, 1944. Marine Biodiversity Records 7: e82. <https://doi.org/10.1017/S175526721400061X>
- Alves OFS, Cerqueira WRP (2000) Echinodermata das praias de Salvador (Bahia, Brasil). Revista Brasileira de Zoologia 17(2): 543–553. <https://doi.org/10.1590/S0101-8175200000200024>
- Benitez-Villalobos F (2001) Comparación de la comunidad de Equinodermos, asociada a arrecifes, en dos localidades de las Bahías de Huatulco, Oaxaca, México. Ciencia y mar 5: 31–36.
- Campos E, Solis-Marín FA (1998) New records of crabs (Pinnotheridae) symbiotic with irregular echinoids in Cuba. Caribbean Journal of Science 34 (3–4): 329–330.
- Caso ME (1978) Ciência y técnica de los Equinodermos en relación con el hombre. Primeira parte—aspecto científico. Anales del Centro de Ciencias del Mar y Limnología 6 (1): 255–286.
- Clark HL (1933) A handbook of the littoral echinoderms of Porto Rico and the other West Indian islands—scientific survey of Porto Rico and the Virgin Islands. New York Academy of Sciences 16: 1–147.
- Fernandes MLB, Tommasi LR, Lima EJB (2002) Filo Echinodermata de Pernambuco. In: Tabarelli M, Silva JMC (Eds) Diagnóstico da Biodiversidade de Pernambuco. Massangana, Recife, 405–427.
- Francisco V, Pauls SM (2008) Especies del orden Clypeasteroidea (Echinodermata: Echinoidea) de las costas de Venezuela. Revista Biologica Tropical 56 (3): 215–228. <https://doi.org/10.15517/rbt.v56i3.27085>
- GBIF (2013) The Global Biodiversity Information Facility: GBIF Backbone Taxonomy, 2013-07-01. <http://www.gbif.org/species/2279044>. Accessed on 2015-1-15.
- Gondim AI, Giacometti ACM (2010) Equinodermos. In: Giacometti ACM, Loebmann D (Eds) Biodiversidade do Litoral do Piauí. Gráfica e Editora Paratodos Sorocaba, Teresina, 129–133.
- Gondim AI, Dias TLP, Christoffersen ML (2013) Annotated checklist of Echinoderms from Maranhão and Piauí states, northeastern Brazil. Check List 9(3): 510–518. <https://doi.org/10.15560/9.3.510>
- Gondim AI, Dias TLP, Christoffersen ML (2015a) First record of basket stars *Astrocyclus caecilia* (Lütken, 1856) and *Astrophyton muricatum* (Lamarck, 1816) (Echinodermata, Ophiuroidea, Euryalida) for the state of Rio Grande do Norte, northeastern Brazil. Check List 11 (1): 1541. <https://doi.org/10.15560/11.1.1541>
- Gondim AI, Dias TLP, Christoffersen ML (2015b) Hypersaline mangroves harbor a high density of Brazilian endangered sea stars (*Echinaster* spp.). Marine Biodiversity 45 (4): 629–630. <https://doi.org/10.1007/s12526-014-0306-4>
- Gondim AI, Dias TLP, Christoffersen ML, Stöhr S (2015c) Redescription of *Hemieuryale pustulata* von Martens, 1867 (Echinodermata, Ophiuroidea) based on Brazilian specimens, with notes on systematics and habitat association. Zootaxa 3925 (3): 341–360. <https://doi.org/10.11646/zootaxa.3925.3.2>
- Gondim AI, Dias TL, Manso CLC (2012) Updated morphological description of *Asteropora* (*Asteropora*) *annulata* (Euryalida: Gorgonocephalidae) from the Brazilian coast, with notes on the geographic distribution of the subgenus. Revista de Biología Marina y Oceanografía 47 (1): 141–146. <http://dx.doi.org/10.4067/S0718-19572012000100013>.
- Gondim AI, Dias TL, Duarte RCS, Riul P, Lacouth P, Christoffersen ML (2014a) Filling a knowledge gap on the biodiversity of rhodolith-associated Echinodermata from northeastern Brazil. Tropical Conservation Science 7 (1): 87–99. <https://doi.org/10.1177/194008291400700112>
- Gondim AI, Christoffersen ML, Dias TLP (2014b) Taxonomic guide and historical review of starfishes in northeastern Brazil (Echinodermata, Asteroidea). ZooKeys 449: 1–56. <https://doi.org/10.3897/zookeys.449.6813>
- Gondim AI, Lacouth P, Alonso C, Manso CLC (2008) Echinodermata from Cabo Branco Beach, João Pessoa, Paraíba, Brazil. Biota Neotropica 8 (2): 151–159. <http://dx.doi.org/10.1590/S1676-06032008000200016>.
- Hadel VF, Monteiro AMG, Ditadi ASF, Tiago CG, Tommasi LR (1999) Echinodermata. In: Migotto A, Tiago CG (Eds) Biodiversidade do Estado de São Paulo, Brasil: Síntese do Conhecimento ao Final do Século XX – Parte 3: Invertebrados Marinhos. FAPESP, São Paulo, 261–271.
- Hendler G, Miller JE, Pawson DL, Kier PM (1995) Sea Stars, Sea Urchins and Allies: Echinoderms of Florida and the Caribbean. Smithsonian Institution Press, Washington DC, 392 pp.
- Herrera-Moreno A, Betancourt L (2013) Recent echinoderms for Hispaniola Island. In: Alvarado JJ, Solis-Marín FA (Eds) Echinoderms Research and Diversity in Latin American. Springer, Berlin, 425–436.
- Kier PM (1975) The echinoids of Carrie Bow Cay, Belize. Smithsonian Contributions to Zoology 206: 1–45. <https://doi.org/10.5479/si.00810282.206>
- Lavrado HP, Ignacio BL (2006) Biodiversidade Bentônica da Costa Central da Zona Econômica Exclusiva brasileira. Museu Nacional, Rio de Janeiro, 389 pp.
- Lima EJB, Fernandes MLB (2009) Diversidade de equinodermos (Echinodermata) no Estado de Pernambuco, Brasil. Revista Brasileira de Zootecias 11(1): 55–63.
- Lima MLF, Correia MD, Sovierzoski HH, Manso CLC (2011) New records of Ophiuroidea (Echinodermata) from shallow waters off Maceió, Alagoas, Brazil. Marine Biodiversity Records 4: 1–10. <https://doi.org/10.1017/S175526721100090X>
- Lima-Verde JC (1969) Primeira contribuição ao inventário dos equinodermos do nordeste brasileiro. Arquivos de Ciências do Mar 9 (1): 9–13.
- Magalhães WF, Martins LR, Alves OFS (2005) Inventário dos Echinodermata do Estado da Bahia. Brazilian Journal of Aquatic Science and Technology 9 (1): 59–63. <https://doi.org/10.14210/bjast.v9n1.p61-65>
- Manso CLC, Alves OFS, Martins LR (2008) Echinodermata da Baía de Todos os Santos e Baía de Aratu (Bahia, Brasil). Biota Neotropica 8 (3): 179–196. <http://dx.doi.org/10.1590/S1676-06032008000300017>
- Manso CLC, Gondim AI, Ventura CRR (2014) New records of Ophiuroidea (Echinodermata) of the Brazilian coast, with notes on its taxonomy and distribution. Marine Biodiversity Records 7: e124. <https://doi.org/10.1017/S1755267214001237>
- Martins IX, Queiroz ACM (2006) Echinodermos do litoral do Estado do Ceará. In: Matthews-Cascon H, Lotufo TMC (Eds) Biota Marinha da Costa Oeste do Ceará. Ministério do Meio Ambiente, Brasília, 199–220.
- McClintock JB, Marion KR (1993) Predation by the King Helmet (*Cassius tuberosa*) on Six-holed Sand Dollars (*Leodia sexiesperforata*) at San Salvador, Bahamas. Bulletin of Marine Science 52 (3): 1013–1017.
- Miranda ALS, Lima MLF, Sovierzoski HH, Correia MD (2012) Inventory of the Echinodermata collection from the Universidade Federal de Alagoas. Biota Neotropica 12 (2): 135–146. <http://dx.doi.org/10.1590/S1676-06032012000200014>
- Mooi R (1986a) Structure and function of clypeasteroid miliary spines (Echinodermata, Echinoidea). Zoomorphology 106 (4): 212–223. <https://doi.org/10.1007/BF00312042>
- Mooi R (1986b) Non-respiratory podia of clypeasteroids (Echinodermata, Echinoidea): II. Diversity. Zoomorphology 106 (2): 75–90. <https://doi.org/10.1007/BF00312110>
- Mooi R, Peterson D (2000) A new species of *Leodia* (Clypeasteroidea: Echinoidea) from the Neogene of Venezuela and its importance in the phylogeny of mellitid sand dollars. Journal of Paleontology 74 (6): 1083–1092.
- Moraes SASN, Alencar CERD, Thomsen E, Freire FAM (2015) New records of the hairy crab *Pilumnus dasypodus* (Decapoda, Brachyura, Pilumnidae) in northeastern Brazil. Check List 11 (2): 1563. <https://doi.org/10.15560/11.2.1563>
- Oliveira JP, Oliveira J, Manso CLC (2010) Inventário da coleção de equinodermos do LABIMAR, Campus Prof^o Alberto Carvalho, Universidade Federal de Sergipe. Scientia Plena 6 (12): 1–14.
- Pinheiro LS, Coriolano LN, Costa MF, Dias JA (2008) O nordeste bra-

- sileiro e a gestão costeira. *Revista de Gestão Costeira Integrada* 8(2): 5–10. <https://doi.org/10.5894/rgci58>
- Queiroz V, Sales L, Neves E, Johnsson R (2011) *Dissodactylus crinitichelis* Moreira, 1901 and *Leodia sexiesperforata* (Leske, 1778): first record of this symbiosis in Brazil. *Nauplius* 19(1): 63-70. <https://doi.org/10.1590/S0104-64972011000100007>
- QGIS Development Team (2016) QGIS 2.14.0 Chugiak Geographic Information System. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org>
- Rathbun R (1879) A list of the Brazilian echinoderms, with notes on their distribution, etc. *Transactions of the Connecticut Academy of Arts and Science* 5: 139–151. <https://doi.org/10.5962/bhl.title.16126>
- Spalding MD, Fox HE, Allen GR, Davidson N, Ferdana ZA, Finlayson M, Halpern BS, Jorge MA, Lombana A, Lourie SA, Martin KD, Macmanus E, Molnar J, Recchia CA, Robertson J (2007) Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience* 57 (7): 573–583. <https://doi.org/10.1641/B570707>
- Solís-Marín FA, Frontana-Uribe SC, Laguarda-Figueras A, Durán-González A (2011) Catálogo de Autoridades Taxonómicas de la Colección Nacional de Equinodermos del Instituto de Ciencias del Mar y Limnología, UNAM. Base de datos SNIB-CONABIO, GS003, México, DF, 133 pp.
- Telford M (1978) Distribution of two species of *Dissodactylus* (Brachyura: Pinnotheridae) among their echinoid host population in Barbados. *Bulletin of Marine Science* 28: 651–658.
- Telford M (1982) Echinoderm spine structure, feeding and host relationships of four species of *Dissodactylus* (Brachyura: Pinnotheridae). *Bulletin of Marine Science* 32: 584–594.
- Telford M, Mooi R (1986) Resource partitioning by sand dollars in carbonate and siliceous sediments: evidence from podial and particle dimensions. *Biological Bulletin* 171 (1): 197–207. <https://doi.org/10.2307/1541917>
- Tommasi LR (1966) Lista dos equinoides recentes do Brasil. *Contribuições do Instituto de Oceanografia da Universidade de São Paulo. Série Oceanografia Biológica* 11: 1–50.
- Ventura CRR, Lima RPN, Nobre CC, Veríssimo I, Zama PC (2006) Filo Echinodermata. In: Lavrado HP, Ignacio BL (Eds) *Biodiversidade Bentônica da Região Central da Zona Econômica Exclusiva Brasileira*. Museu Nacional, Rio de Janeiro, 339–389.
- Verrill AE (1868) Notice of coral and echinoderms collected by Prof. C. F. Hartt at the Abrolhos Reefs, province of Bahia, Brazil. *Transactions of the Connecticut Academy of Arts and Science* 1: 351–371.