

## ***MOLLUSCS FROM THE UPPER MESOPHOTIC ZONE IN A SCARCELY KNOWN REEF OF THE WESTERN EQUATORIAL ATLANTIC***

Moluscos da zona mesofótica superior de um recife pouco conhecido do Atlântico Equatorial Ocidental

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### **ABSTRACT**

Despite the increasing focus on biodiversity of mesophotic coral ecosystems (MCEs) on a global scale, some biological groups, such as molluscs, are still poorly investigated. The taxonomic diversity of the molluscan fauna of a scarcely known MCE of the Western Equatorial Atlantic, Northeastern Brazil, was surveyed. Samples were collected along the shallower strata of the upper mesophotic zone (between 33-36 m depth). Twenty-one taxa (nine species of gastropods, ten species of bivalves, and two taxa of chitons) were listed, two of which (*Novastoa* sp. and *Thylaeodus* sp.) are potential endemic species. A new northern limit of distribution of *Persicula moscatellii* was established and seven species had new bathymetric records for living specimens (*Barbatia domingensis*, *Barbatia cancellaria*, *Lamychaena hians*, *Leiosolenus bisulcatus*, *Pinctada imbricata*, *Hipponix incurous*, and *Persicula moscatellii*). *Hipponix costellatus* are the most representative species with 49 individuals,

Recebido em: 05/11/2020  
Aprovado em: 13/05/2021  
Publicado on-line em: 20/12/2021

followed by *Lima caribaea* with six individuals. The present work is the first contribution to the knowledge of the molluscan fauna associated with consolidated substrates from this little-known MCE.

**Keywords:** mesophotic coral ecosystems, tropical reef, molluscan diversity, Brazilian Province, conventional SCUBA.

## RESUMO

*Apesar do crescente foco na biodiversidade de ecossistemas de corais mesofóticos (mesophotic coral ecosystems - MCEs) em escala global, alguns grupos biológicos, como os moluscos, ainda são pouco conhecidos. A diversidade taxonômica da fauna de moluscos de um MCE pouco conhecido do Atlântico Equatorial Ocidental, Nordeste do Brasil, foi investigada. As amostras foram coletadas ao longo dos estratos mais rasos da zona mesofótica superior (entre 33 e 36 m de profundidade). Vinte e um táxons (nove espécies de gastrópodes, dez espécies de bivalves e duas espécies de quítons) foram encontrados, dois dos quais (*Novastoa sp.* e *Thylaeodus sp.*) são potenciais espécies endêmicas. Um novo limite norte de distribuição de *Persicula moscatellii* foi estabelecido e sete espécies apresentaram novos registros batimétricos para espécimes vivos (*Barbatia domingensis*, *Barbatia cancellaria*, *Lamychaena hians*, *Leiosolenus bisulcatus*, *Pinctada imbricata*, *Hipponix incurvus* e *Persicula moscatellii*). *Hipponix costellatus* foi a espécie mais representativa, com 49 indivíduos, seguida por *Lima caribaea* com seis indivíduos. O presente estudo é a primeira contribuição ao conhecimento da fauna de moluscos desse MCE pouco conhecido.*

**Palavras-chave:** ecossistemas de corais mesofóticos, recife tropical, diversidade de moluscos, Província Brasileira, SCUBA convencional.

## INTRODUCTION

Mesophotic coral ecosystems (MCEs) occur in tropical and subtropical regions between depths of 30 and 150 m, and are characterised by the presence of light-dependent corals and other organisms typically associated with reef environments (Hinderstein *et al.*, 2010; Pyle & Copus, 2019). MCEs are usually divided into zones, with the shallowest one being called the 'upper mesophotic zone', comprising reef environments between 30 and 60 m depth (Rocha *et al.*, 2018).

In Brazilian waters (South-western Atlantic), MCEs are diversified in structural composition, comprising octocoral or black coral forests, rhodolith beds, sponge bottoms, rocky reefs, and other biogenic reefs (Francini-Filho *et al.*, 2019; Soares; Tavares & Carneiro, 2019). In this region, these ecosystems are distributed from the Great Amazon Reef System (GARS) (5°N) to at least 24°S, including the MCEs in oceanic sites, such as the São Pedro and São Paulo Archipelago, Rocas Atoll, Fernando de Noronha Archipelago, and Vitória-Trindade Chain (Amado-Filho *et al.*, 2016, Francini-Filho *et al.*, 2018, 2019; Pinheiro *et al.*, 2017; Rosa *et al.*, 2016).

Relationships between shallow reef biotas and MCEs have been receiving attention due to their potential use as refuge zones by some species during periods of disturbance (deep reef refugia hypothesis) [(Bongaerts *et al.*, 2010); see new definitions in Bongaerts and

Smith (2019)]. However, some studies have argued that MCEs are unique ecosystems with characteristic biotas, which are also impacted likewise shallow reefs (e.g., Morais & Santos, 2018; Rocha *et al.*, 2018; Medeiros *et al.*, 2021). Despite the emerging scenario focusing on biodiversity of MCEs on a global scale, some biological groups, such as molluscs, are still poorly investigated (Pyle & Copus, 2019). The same knowledge gap is also observed in studies addressing the MCEs of Brazilian waters: although the biodiversity and importance of these ecosystems have been the focus of several recent studies, the surveys focused mainly on rhodolith beds, sponges, scleractinian coral, and fishes (e.g., Amado-Filho *et al.*, 2016; Cordeiro *et al.*, 2015; Feitoza; Rosa & Rocha, 2005; Francini-Filho *et al.*, 2019; Mantelatto; Cruz & Creed, 2018; Morais & Santos, 2018; Moura *et al.*, 2016; Pinheiro *et al.*, 2015; Rocha; Rosa & Feitoza, 2000; Rocha *et al.*, 2018; Rosa *et al.*, 2016; Soares *et al.*, 2018). One exception is the studies of Leal (1991) and Leal and Bouchet (1991) on molluscs (“prosobranch” gastropods) from the MCEs of Fernando de Noronha, Rocas Atoll, and the Vitória-Trindade chain. Recent publication has specifically investigated the scleractinian coral and fishes in the shallower strata of the upper mesophotic zone on the coast of Ceará State (Northeastern Brazil) (Soares *et al.*, 2018). Freitas and Lotufo (2015) also investigated the reef fish assemblages of some reef environments with depths greater than 30 meters, including the area analyzed in this study (Canal das Arabaianas, described below). Nevertheless, the molluscan fauna associated with these MCEs has never been studied.

The present study aims to qualitatively analyse the molluscan fauna on consolidated substrates from the Canal das Arabaianas, a Mesophotic Coral Ecosystems located on the continental shelf adjacent to the Ceará State, northeastern Brazil. This region harbours some of the least studied reef environments of the South-western Atlantic (Castro & Pires, 2001; Freitas & Lotufo, 2015; Pinheiro *et al.*, 2018).

## MATERIAL AND METHODS

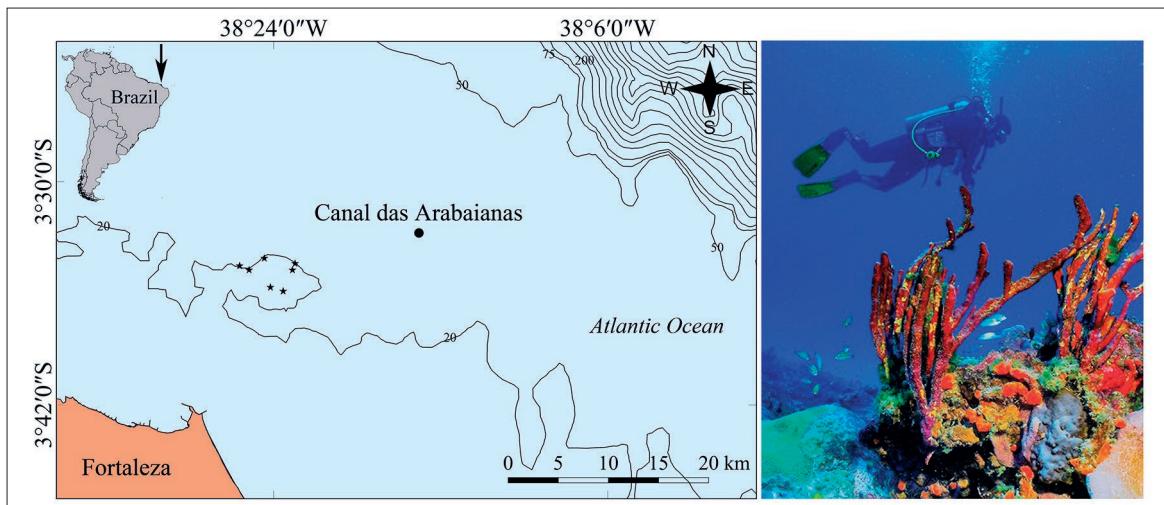
The Canal das Arabaianas is a reef environment located on the northeast coast of Brazil (South-western Atlantic Ocean), approximately 28.5 km off Fortaleza (Ceará State’s capital) (3°32’45.24”S, 38°16’10.74”W) (Figure 1). This site is made up of a patch reefs surrounded by sandy area. Traditionally, this is an artisanal fishing site that is eventually also visited by recreational divers. This reef ecosystem is classified as an MCE due to its depth (greater than 30 m) (*sensu* Hinderstein *et al.*, 2010).

The width of the continental shelf in the study area is approximately 50 km, where different subaqueous features are found, for example: (1) rigid substrates in the form of ancient shorelines (beachrocks) and/or biogenic reefs and (2) unconsolidated substrates such as subaqueous dunes (Morais *et al.*, 2020).

Consolidated substrate samples, including two scleractinian coral species [*Montastrea cavernosa* (Linnaeus, 1767) and *Siderastrea stellata* (Verrill, 1868)], which have already been recorded in another MCE in this region (Soares *et al.*, 2018), and unidentified sponges, were collected during an expedition held on 4 July 2009 by conventional SCUBA diving to access the molluscan fauna, under the permission of an official license (SISBIO permit no. 13983-2). The dives were conducted between 33–36 meters deep. Four researchers collected simultaneously to compensate for the reduced bottom time (15 minutes) provided by conventional SCUBA techniques at the depths required in the present study. Consolidated substrate samples were collected and then stored in labelled plastic bags. The samples

were fixed in 10% formaldehyde in the laboratory, and after 48 hours the formaldehyde was replaced by 70% ethanol. The animals were separated under a stereomicroscope and preserved in 70% ethanol. Molluscs were identified to the lowest possible taxonomic level using appropriate references (*e.g.*, Boyer, 2004; Mikkelsen & Bieler, 2003; Rios, 2009; Rosenberg, 2009; Warmke & Abbott, 1962) and by comparison with the lots deposited at the following malacological collections: Prof. Henry Ramos Matthews - series B, Universidade Federal do Ceará (UFC), CE, Brazil (CMPHRM-B), and Museu Oceanográfico Prof. Eliézer de Carvalho Rios, Universidade Federal do Rio Grande (FURG), RS, Brazil (MORG). All collected material was incorporated in the same Institutions (CMPHRM-B and MORG).

Figure 1 - Geographic location of the studied area, NE Brazil. Black circle highlights the Canal das Arabaianas MCE (33-36 meters deep). Black stars point out the location of natural reef environments with intermediate depths (~16 to 26 m), which are located within the Pedra da Risca do Meio Marine State Park. The bathymetric data used were provided by the Geological Survey of Brazil (CPRM) and National Agency for Petroleum, Natural Gas and Biofuels (ANP)



Source: <http://www.cprm.gov.br/publique/Geologia/Geologia-Marinha/Projeto-Batimetria-3224.html>). On the right, a photograph of the study area. Photo: Leo Francini.

## RESULTS

We found three classes of Mollusca: Bivalvia, Gastropoda, and Polyplacophora (81 specimens, Table I, Figure 2). Bivalvia was represented by ten species from eight families (Arcidae, Chamidae, Cardiidae, Gastrochaenidae, Limidae, Malleidae, Mytilidae, and Pteriidae). The most representative bivalve species was *Lima caribaea* d'Orbigny, 1842, with six individuals. Gastropoda, in turn, was represented by nine species from seven families, with Hipponicidae [*Hipponix costellatus* Carpenter, 1856 and *Hipponix incurvus* (Gmelin, 1791)] being the most representative with 51 individuals. The other families of gastropods were: Cerithiopsidae, Cypraeidae, Marginellidae, Ranellidae, Vermetidae, and Zebinidae. Two specimens of Polyplacophora were identified - *Acanthochitona* sp. and *Acanthochitona* cf. *terezae* Guerra Júnior, 1983) (Table I, Figure 2).

All the molluscs identified to species-level had already been recorded for the coast and/or island environments of Brazil, with the majority having wide geographic distributions (Table I). The present study reported three new records of occurrence for the gastropods *Persicula moscatellii* Boyer, 2004, whose previous northern limit on the Brazilian coast



was the Rio Grande do Norte State; and the vermetids *Novastoa* sp. and *Thylaeodus* sp., two potential endemic species registered for the first time in the Ceará State. We do not consider the presence of *Schwartzziella fischeri* (Desjardin, 1949) in the Canal das Arabaianas as a new complete occurrence record, because we found only an empty shell. Therefore, we await a future record (including soft parts) to confirm this occurrence. We also do not consider the occurrence of *Acanthochitona* cf. *terezae* as a new geographical record, since species identification has not been confirmed.

Our study also reported new bathymetric records for living specimens of *Barbatia domingensis* (Lamarck, 1819), *Barbatia cancellaria* (Lamarck, 1819), *Lamychaena hians* (Gmelin, 1791), *Leiosolenus bisulcatus* (d’Orbigny, 1853), *Pinctada imbricata* Roding, 1798, *H. incurvus*, and *Persicula moscatellii* (Table I).

Table I - Species of Mollusca collected in the Canal das Arabaianas MCE, Western Equatorial Atlantic

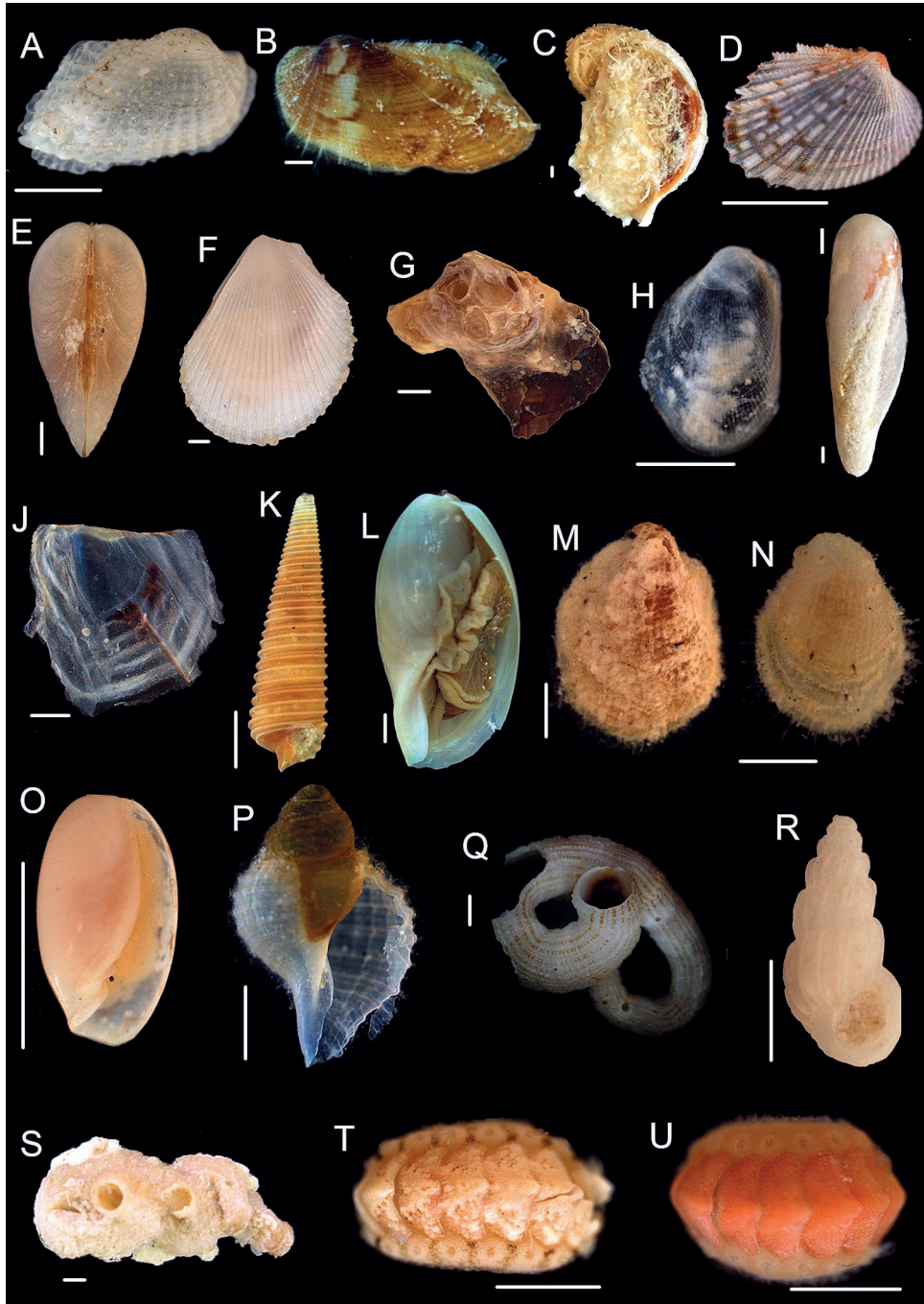
Class/ Family	Species	Number of individuals	Voucher number	Geographical <sup>a</sup> distribution	and	bathymetric <sup>b</sup>
<b>Bivalvia</b>						
	<i>Barbatia domingensis</i> (Lamarck, 1819)	2	CMPHRM6389B	Bermuda, North Carolina to Texas, Caribbean Sea, Venezuela to Brazil (São Pedro and São Paulo Archipelago). From 0 to 140 m (live 4 to 36 m).		
Arcidae	<i>Barbatia cancellaria</i> (Lamarck, 1819)	1	CMPHRM6391B	North Carolina to Florida, Texas, Caribbean Sea, Venezuela, Surinam, and Brazil (Fernando de Noronha Archipelago, Pará to Bahia). From 0 to 85 m (live 0 to 36 m).		
Chamidae	<i>Chama</i> sp.	1	CMPHRM6383B	-		
Cardiidae	<i>Papyridea semisulcata</i> (J.E. Gray, 1825)	1*	CMPHRM6401B	Bermuda, South Florida, Caribbean Sea, and Brazil (Fernando de Noronha Archipelago, Trindade Island, Pará to Rio de Janeiro). From 0 to 100 m.		
Gastrochaenidae	<i>Lamychaena hians</i> (Gmelin, 1791)	2	CMPHRM6390B	Bermuda, North Carolina to Texas, Caribbean Sea, Venezuela, Surinam to Brazil (Ceará to Santa Catarina; Abrolhos Archipelago). From 0 to 80 m (live 0 to 36 m).		
Limidae	<i>Lima caribaea</i> (d’Orbigny, 1842)	6	CMPHRM6386B	Bermuda, North and South Carolina, Florida and the Florida Keys, Texas, the Bahamas, Caribbean Sea, and South America to Brazil (Fernando de Noronha Archipelago, Amapá to Rio de Janeiro). From the shallow subtidal to 311 m (living specimens).		
Malleidae	<i>Malleus candeanus</i> (d’Orbigny, 1853)	2	CMPHRM6392B	Bermuda, South Florida to Texas, Caribbean Sea, Brazil (Amapá to Bahia, Abrolhos Archipelago). From 1 to 548 m.		
	<i>Brachidontes</i> sp.	3	CMPHRM6396B	-		
Mytilidae	<i>Leiosolenus bisulcatus</i> (d’Orbigny, 1853)	2	CMPHRM6385B	North Carolina to Florida, Texas, Caribbean Sea, Venezuela, Surinam, and Brazil (Fernando de Noronha Archipelago, Trindade Island, Maranhão to São Paulo); Ascension Island; St. Helena. From 0 to 80 m (live 1 to 36 m).		
Pteriidae	<i>Pinctada imbricata</i> (Roding, 1798)	1	CMPHRM6400B	Bermuda, North Carolina to Florida, Texas, Caribbean Sea, Venezuela, and Brazil (Pará to Santa Catarina). From 0 to 36 m.		
<b>Gastropoda</b>						
Cerithiopsidae	<i>Seila adamsii</i> (H.C. Lea, 1845)	1*	CMPHRM6387B	North Carolina to Florida, Texas, Caribbean Sea, Venezuela, Brazil to Uruguay. From 0 to 80 m (live 0 to 20 m).		

(continuation Table I)

Class/ Family	Species	Number of individuals	Voucher number	Geographical <sup>a</sup> distribution and bathymetric <sup>b</sup>
Cypraeidae	<i>Cypraea</i> cf. <i>zebra</i> (Linnaeus, 1758)	1	CMPHRM6388B	N. Carolina to Florida, Texas, W. Indies, E. Colombia, Venezuela, Surinam, Brazil (Maranhão to Santa Catarina, Trindade Island). From 0 to 10 m.
Hipponicidae	<i>Hipponix costellatus</i> (Carpenter, 1856)	49	CMPHRM6384B	Brazil (Rocas Atoll, Fernando de Noronha Archipelago, Trindade Island, Ceará to South Bahia, Abrolhos Archipelago) and St. Helena. from 0 to 60 m (live 0 to 54 m).
	<i>Hipponix incurvus</i> (Gmelin, 1791)	2	CMPHRM6395B	North Carolina to Florida, Caribbean Sea, East Colombia, Venezuela to Brazil (Fernando de Noronha Archipelago, Vitória-Trindade Chain, Amapá to Santa Catarina, Abrolhos Archipelago). From 0 to 538 m (live 6 to <u>36</u> m).
Marginellidae	<i>Persicula moscatellii</i> (Boyer, 2004)	1	CMPHRM6394B	French Guiana and Brazil ( <u>Ceará</u> to Bahia). From 20 to 250 m (live 20 to <u>36</u> m)
Ranellidae	<i>Cymatium</i> sp.	1	CMPHRM6397B	-
Vermetidae	<i>Novastoa</i> sp.	4	MORG53731	-
	<i>Thylaeodus</i> sp.	1	MORG53732	-
Zebinidae	<i>Schwartziella fischeri</i> (Desjardin, 1949)	1*	CMPHRM6393B	Bermuda, Cuba, Caribbean Sea, and Brazil (Rocas Atoll, Fernando de Noronha Archipelago, and Abrolhos Archipelago). From 0 to 55 m (live 0 to 10 m).
<b>Polyplacophora</b>				
Acanthochitonidae	<i>Acanthochitona</i> sp.	1	CMPHRM6399B	-
	<i>Acanthochitona</i> cf. <i>terrezae</i> (Guerra Júnior, 1983)	1	CMPHRM6398B	Brazil (Fernando de Noronha Archipelago, <u>Ceará</u> ** <sup>a</sup> , Bahia, Espírito Santo). From 0 to 63 m.

Legend: CMPHRM-B - Prof. Henry Ramos Matthews - series B Malacological Collection, Universidade Federal do Ceará, Brazil; MORG - Museu Oceanográfico Prof. Eliézer de Carvalho Rios, Universidade Federal do Rio Grande - FURG, RS, Brazil. \* Only shell or valve; \*\* Record to be confirmed; <sup>a</sup>References: Mikkelsen and Bieler (2003); Boyer (2004); Rios (2009); Jardim, Almeida and Simone (2017), and present study; <sup>b</sup>References: Mikkelsen and Bieler (2003); Rios (2009); Rosenberg (2009); Jardim, Almeida and Simone (2017), and present study; underlined names and numbers: new geographic or bathymetric record.

Figure 2 - Species of Mollusca collected in the Canal das Arabaianas MCE, Western Equatorial Atlantic. **a.** *Barbatia domingensis* (Lamarck, 1819); **b.** *Barbatia cancellaria* (Lamarck, 1819); **c.** *Chama* sp.; **d.** *Papyridea semisulcata* (J.E. Gray, 1825); **e.** *Lamychaena hians* (Gmelin, 1791); **f.** *Lima caribaea* (d'Orbigny, 1842); **g.** *Malleus candeanus* (d'Orbigny, 1853); **h.** *Brachidontes* sp.; **i.** *Leiosolenus bisulcatus* (d'Orbigny, 1853); **j.** *Pinctada imbricata* (Roding, 1798); **k.** *Seila adamsii* (H. C. Lea, 1845); **l.** *Cypraea* cf. *zebra*; **m.** *Hipponix costellatus* (Carpenter, 1856); **n.** *Hipponix incurvus* (Gmelin, 1791); **o.** *Persicula moscatellii* (Boyer, 2004); **p.** *Cymatium* sp.; **q.** *Novastoa* sp.; **r.** *Schwartziella fischeri* (Desjardin, 1949); **s.** *Thylaeodus* sp.; **t.** *Acanthochitona* sp.; **u.** *Acanthochitona* cf. *terezae* (Guerra Júnior, 1983). Scale bars = 1 mm



## DISCUSSION

The species found in MCE Canal das Arabaianas are typical of consolidated substrates, such as corals, rocks, and shells, or living in association with marine sponges [e.g., *P. imbricata* and *Malleus candeanus* (d'Orbigny, 1853)] and the coralline algae *Neogoniolithon* sp. [e.g., *Novastoa* sp. and *Thylaeodus* sp.] (Culliney, 1971; Mikkelsen & Bieler, 2003; Moran, 2004; Rios, 2009; Spotorno-Oliveira; Tâmega & Bemvenuti, 2012).

The vermetids *Novastoa* sp. and *Thylaeodus* sp. could be considered potential endemic species from Canal das Arabaianas. *Novastoa* sp. can readily be distinguished from the same taxon (named as *Dendropoma* sp.) previously recorded at the oceanic islands (Rocas Atoll and Fernando de Noronha Archipelago) and along the Northeast Brazilian coast (Maranhão, Alagoas, and Bahia) (Spotorno-Oliveira; Tâmega & Bemvenuti, 2012), by the shell and pre-hatching larval shells extracted from egg masses. The genus *Novastoa* Finlay, 1926 was recognised by Golding *et al.* (2014) after revising the genus *Dendropoma* Mörch, 1861 (*s. lat.*) both from a molecular and morphological analyses. *Thylaeodus equatorialis* Spotorno and Simone, 2013, a species endemic to the São Pedro and São Paulo Archipelago, located at the mid-equatorial Atlantic Ocean (Spotorno & Simone, 2013), is the unique known *Thylaeodus* to the Brazilian coast and is easily distinguished by shell sculpture.

In this study, all specimens identified at species level have wide geographical distributions in the Western Atlantic (from the North to South Atlantic), including coastal and insular environments, except for *Hipponix costellatus* (endemic to Brazilian coast and oceanic islands) and *Persicula moscatellii* (coast of French Guyana and Brazil), which have a more restricted geographical distribution (Table I). Among these species, besides *H. costellatus*, *H. incurvus*, *B. domingensis*, *B. cancellaria*, *L. bisulcatus*, *Lima caribaea* d'Orbigny, 1842, and *Papyridea semisulcata* (J.E. Gray, 1825) are also distributed on both the Brazilian coast and the oceanic islands (São Pedro and São Paulo Archipelago, Rocas Atoll, Fernando de Noronha Archipelago, and/or Trindade Island) (Table I). The larval development type and/or the presence of a seamounts chain could explain both wide geographical distribution and faunistic similarity between coast and oceanic islands.

Species with planktotrophic development are expected to have higher dispersion potential (broader geographic distribution) than those with non-planktotrophic larvae or a short planktonic period (Jablonski & Lutz, 1983; Moran, 2004; Thorson, 1950). *Barbatia domingensis*, *B. cancellaria*, and *L. bisulcatus* have planktotrophic larvae (Culliney, 1971; Moran, 2004) and wide geographical distributions (Table I). The larvae of *L. bisulcatus* can delay metamorphosis that could account for the extensive geographical distribution of this species (Culliney, 1971). Hipponicidae species (e.g., *H. costellatus* and *H. incurvus*) contrarily, found in coastal and oceanic Western Atlantic environments, have a short veliger stage (Rios, 2009). The presence of a seamount chain, which can function as stepping stones, linking coastal areas to oceanic islands, can increase the dispersion potential of these species (Barroso *et al.*, 2016; Pinheiro *et al.*, 2017; Simon; Macieira & Joyeux, 2013). Fernando de Noronha Archipelago and Rocas Atoll are part of an alignment of seamounts of the Brazilian Equatorial Margin, with an east-west orientation, reaching close to the coast of Ceará State (NE Brazil) (Jovane *et al.*, 2016; Morais, 1969; Moura *et al.*, 2019), while Trindade Island is part of the Vitória-Trindade Chain (SE Brazil) (Pinheiro *et al.*, 2017). Unfortunately, there is no specific information about the larval development of *L. caribaea* (Limidae) and *P. semisulcata* (Cardiidae), but Limidae species have different development



strategies (planktotrophic larvae, lecithotrophic larvae, and brooding) (Linse & Page, 2003) and some species of Cardiidae have planktotrophic larvae (Günther & Fedyakov, 2000).

In some localities, the shallow and mesophotic reefs are only a few dozen meters apart, providing a higher possibility of vertical connectivity (e.g., Kramer *et al.*, 2019). In other cases, such as in our study region, shallow coastal and upper mesophotic reefs are interspersed by kilometres of unconsolidated substrate (Morais *et al.*, 2020). The presence of coralline algae as substrate for molluscs physically modifies the reef environment and provides hard substrate and microhabitats for larval settlement in a range of marine invertebrates (e.g., Golbuu & Richmond, 2007; Hayakawa *et al.*, 2008; Spotorno-Oliveira; Figueiredo & Tâmega, 2015; Swanson *et al.*, 2006). Also, the coralline algae increase the biodiversity in soft-bottom areas and provide refuges for several organisms (Kamenos *et al.*, 2004; Figueiredo *et al.*, 2007; Steller *et al.*, 2003).

Despite this clear spatial separation, our results showed that there might be a connection between the Canal das Arabaianas and shallow coastal reefs located in the intertidal and sublittoral zones since they share common species. More specifically, 33% of surveyed species [*L. caribaea*, *B. cancellaria*, *L. hians*, *L. bisulcatus*, *P. imbricata*, *Seila adamsii* (H.C. Lea, 1845), and *Cypraea cf. zebra* (Linnaeus, 1758)] have already been found in the Ceará coast intertidal reefs, according to the records (only specimens with soft parts) of the malacological collection CMPHRM-B. As highlighted in Figure 1, the natural reef environments, located between the coastal reefs and the studied MCE in intermediate depths (~16 to 26 m) (Freitas & Lotufo, 2015; Freitas; Araújo & Lotufo, 2019; Soares *et al.*, 2017), may act as stepping stones and facilitate connection between depth extremes (Bongaerts *et al.*, 2017; Holstein *et al.*, 2016). However, the coexistence of species in adjacent shallow and mesophotic reefs alone is not sufficient to confirm connectivity over ecological time scales. Bongaerts *et al.* (2017), studying two species of scleractinian corals from shallow and upper mesophotic zones using a next-generation sequencing approach (RAD-seq), found high or very low contemporary connectivity levels, depending on the studied species. It is possible that other biological groups, such as molluscs, may have different levels of vertical connectivity in function of species with distinct life-history traits.

Although some low environmental impact techniques commonly used to study the diversity of MCEs (e.g., visual censuses by divers or analysis of videos captured by remotely operated vehicles - ROVs) are efficient for some biological groups, such as anthozoans and fishes (e.g., Cabaitan *et al.*, 2019; Rocha *et al.*, 2018), they do not appear to be suitable for recording molluscan diversity. Easton *et al.* (2019), studying the MCEs of Rapa Nui (Easter Island), found that most species found in substrate samples were not observed during ROV imaging surveys. The authors highlighted the need to collect substrate in an initial effort to determine unknown diversity and distribution of molluscan species. The small size of the specimens found in the present study shows that it is challenging to identify species without material collection and subsequent laboratory analysis. Although manual collections, such as the one performed in the present study, have a lower impact when compared to sampling using trawls and dredges, one possible alternative with less impact is the use of recruitment structures that simulate the complexity of reef environments, such as ARMS (Autonomous Reef Monitoring Structures) (Plaisance *et al.*, 2011). This methodology, combined with metabarcoding techniques, has already been shown to be efficient for studying the diversity of cryptic fauna in MCEs (Ransome *et al.*, 2017).

In conclusion, this study presents, for the first time, data about the malacofauna associated with consolidated substrate in MECs in the Ceará State, reporting new records of occurrence and new bathymetric records for some species. Recently, with the greater access by researchers to advanced diving technologies (e.g., closed-circuit rebreathers), several new species that inhabit MECs are being described, in some cases, at rates higher than those observed in shallow reefs (Pinheiro *et al.*, 2019). In view of the different anthropic impacts that affect MCEs on a global scale (Rocha *et al.*, 2018; Soares *et al.*, 2020a), or even in the study region, where industrial fishing for mesophotic species has occurred since the 1960s (Fonteles-Filho, 2007; Francini-Filho *et al.*, 2019) and an invasive species, the sun coral *Tubastraea tagusensis* Wells, 1982, has been recorded recently in intermediate (~ 22 m) and mesophotic (~ 32 m) artificial reefs (shipwrecks) (Soares; Davis & Carneiro, 2018; Soares *et al.*, 2020b), it is possible that part of the diversity of these ecosystems is lost even before it was known. Thus, studies in these areas should be stimulated in order to deepen the knowledge about the biota of the MCEs and consequently base more efficient conservation strategies, for example, including mesophotic reef environments in the design of networks of protected areas.

**Acknowledgements** – The authors would like to thank Dr. Tito M.C. Lotufo for his support in the fieldwork and laboratory. The authors also wish to thank the photographer Leo Francini for the image of the Canal das Arabaianas used in this study and the Dr. Jaime Jardim for the identification of chitons. The Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) provided a postdoctoral fellowship to C.X. Barroso (PNPD process number 88882.306440/2018-01), João Eduardo Pereira de Freitas (PNPD, process number 88887.466769/2019-00), P. Spotorno-Oliveira (PNPD, process number 88887.320380/2019-00), and F.T.S. Tâmega (PNPD, process number 88882.314604/2019-01).

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